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Some Factors Influencing the Culinary Quality of Southern and Northern Grown Irish Potatoes.

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SOME FACTORS INFLUENCING THE CULINARY QUALITY OF SOUTHERN AND NORTHERN GROWN IRISH POTATOES

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ABSTRACT

Surveys have shown that housewives and food processors prefer a mealy, white fleshed Irish potato tuber. Less mealy potatoes are generally used for boiling or salad purposes. However, mealiness is considered to be the standard of Irish potato culinary quality by most authorities in the United States.

This research was undertaken in an effort to correlate variations in mealiness with certain physical characteristics and the chemical composition of southern grown Irish potato tubers, and tubers of the same varieties from a northern area.

Four Irish potato varieties, grown at a northern and a southern location, were included in this study. They were: Red LaSoda, Sebago, White Rose, and Russet Burbank, grown at Rhinelander, Wisconsin, and Baton Rouge, Louisiana. Environmental and cultural conditions were similar for all varieties at a location. Spring and fall crop tubers were grown at Baton Rouge and compared in quality studies with tubers of the same varieties produced at Rhinelander. Four harvests, at different dates, were made of the southern spring and fall crops.

The specific gravity and dry matter content of tubers were determined by means of a potato hydrometer. Mealiness was judged by a taste panel, following analyses of tubers for total starch, amylose and amylopectin, sugar and protein content. Anatomical studies and measurements of cell and starch grain size were also made.

There were marked variations in specific gravity, dry matter content, chemical composition, cell and starch grain size, and mealiness of tubers between varieties, locations and dates of harvest. Those of the Russet Burbank variety were highest in mealiness. Red LaSoda potatoes were lowest in mealiness, while those of the Sebago and White Rose varieties were at an intermediate level. Tubers produced at the northern location were superior to those of the spring or fall crops at the southern location. Fall potatoes were of higher quality than those grown during the spring at the southern location.

Based on this study, it appears that specific gravity, chemical composition, cell size, and starch grain size may be related to mealiness of potato tubers. However, some of these relationships have not proven entirely consistent.

INTRODUCTION

The culinary quality of the Irish potato (Solanum tuberosum, Linn.), has been a frequent subject for research. Results as interpreted have often been contradictory, reportedly because objective and uniform standards for judging quality have not been developed, and knowledge of the changes which occur during cooking has been elusive.

Surveys (12, 18, 21, 23) have shown that housewives and food processors generally prefer a mealy, white fleshed Irish potato. Tubers which are less mealy have been widely used for boiling or salad purposes. However, mealiness is considered to be the standard of Irish potato culinary quality by most authorities in the United States.

Much of the research on potato tuber quality has been directed towards determining the factors related to mealiness, and is generally grouped into those of a physical and of a chemical nature. No precise method of predicting the quality of the cooked product has yet been devised, although specific gravity is considered the most practical index. A positive correlation between the specific gravity and dry matter content of tubers has generally been demonstrated. Workers and food processors have used specific gravity as a measure of the dry matter content, and an indication of quality in Irish potatoes. High specific gravity is usually associated with high dry matter content and quality.

This study was designed to correlate possible variations in mealiness with physical properties and chemical composition of southern grown Irish potatoes, and tubers of the same varieties grown in a northern location. Since most southern grown potatoes are generally of lower mealiness than most northern grown tubers, a knowledge of the factors related to mealiness in potatoes could prove helpful in the breeding, selection and culture of varieties which would possess higher mealiness. Tubers having this quality would be excellent for household use, perhaps provide southern potato processors with locally grown varieties, and decrease the problems and costs of shipping and storing potatoes from other areas as is now necessary for many potato processors in the south.

REVIEW OF LITERATURE

The specific gravity of potato tubers has been shown to be closely related to their total dry matter content, which is considered a measure of quality (29). However, exceptions to a correlation between specific gravity and mealiness have been reported (21, 25, 40, 52). Interpretation of results has varied considerably, but generally no positive correlation between specific gravity and mealiness was obtained. Hawkins et al (21) reported that specific gravity did not correctly indicate the starch content, nor by inference the mealiness of potatoes. This was particularly true of potatoes stored at high (75 degrees F.) or low temperatures (35 degrees F.), due to underestimation of starch at high temperatures, and overestimation of starch at low temperatures, when compared with specific gravity.

Other investigators have found discrepancies in the relationship between specific gravity and mealiness of potato tubers. Kirpatrick (25), working with four varieties of early-crop potatoes, found no significant relationship between specific gravity and mealiness in boiled, baked, or mashed potatoes. Such a correlation should have existed, she pointed out, since a significant difference existed between specific gravity and dry matter, and mealiness and dry matter content, as determined by taste panels.

Schark (40) found that differences between the specific gravity of several varieties of potato tubers were significant when compared with mealiness scores of taste judges. However, he also concluded that there was some factor other than specific gravity which influenced the evaluation of mealiness in the tubers tested by the judges. This opinion was based on the fact that tubers showing the same specific gravity differed in mealiness when assessed by taste panels. It was suggested that further studies be made to determine what characteristics, in addition to dry matter content, influenced mealiness.

Further limitations of the specific gravity method were pointed out by Whittenberger (52). He showed that the relationship between specific gravity and sloughing, the disintegration during cooking which is common among mealy potatoes, depended partly upon the physiological condition and storage history of the potatoes. The amount of sloughing could decrease or increase without any change in specific gravity, or sloughing could even decrease as specific gravity increased. The accuracy of specific gravity for indicating starch content also varied with storage condition; least accuracy being with tubers stored at low (35 degrees F.) temperatures.

Miller, Sistrunk, and Webb (30) stated that specific gravity apparently was not the limiting factor responsible for potato chip quality. There seemed to be no definite relationship between specific gravity and mealiness among the varieties evaluated in this work.

Specific gravity of potato tubers was reportedly influenced by several known factors. Some seemed to have only minor effects, while others resulted in a significant increase or decrease in specific gravity readings (5).

Stevenson (46, 47), found inherent varietal differences in the dry matter content of tubers, but also reported that often the differences caused by environment were greater than genetic factors. Tubers of the same variety grown at different locations varied more in specific gravity than those of different varieties grown at the same location. Some environmental factors influencing dry matter content were soil, location, date of planting, date of harvest, fertilizer, temperature, and moisture.

Summarizing work done at Cornell, Ora Smith (43) reported that many factors influenced specific gravity and corresponding culinary quality of Irish potatoes. As a general classification, environment was the most important influencing factor, with varietal differences secondary. Culinary quality was as variable for a given variety grown at different locations as it was between varieties grown at the same location. Temperatures during the growing season, when moisture supply was low, had considerable influence on quality, especially when low moisture supply was coupled with high temperature. These conditions resulted in low specific gravity tubers, due to greater respiration and larger loss of dry matter from the tubers. Delayed maturity of the tubers, due to any factor, resulted in decreased specific gravity readings.

Among the factors causing delayed maturity were amount and kind of fertilizer, planting date, harvest date, vine killing practices, and the insect or disease control program.

Heinze et al (22) reported that dry matter, alcohol insoluble solids, and starch were good measures of potato culinary quality, but this quality varied considerably. Ratings of tubers by taste panels showed that mealiness was influenced as much by location and growing conditions as it was by varietal differences. Tubers of the Katahdin variety produced at one location were among the mealiest, while tubers of the same variety grown in another location were among the least mealy. Cooking methods of various types made little difference in the mealiness, dryness, or flavor of tubers of the different varieties tested.

The specific gravity of potato tubers, according to Bonde (6) was lowered by any factor which caused premature death of the plants. Among these factors were defoliation by disease and insect infestation. A long growing season was favorable for production of potatoes of high specific gravity. Shortening the growing period, by any means, resulted in potatoes which were of lower specific gravity.

Haddock and Blood (18) showed that potatoes of identical specific gravity, but grown at different locations, differed in mealiness. Nylund and Poivan (35) reported that potatoes of identical specific gravity varied in mealiness, depending on the date of planting and the variety.

From a physico-chemical standpoint, as related to mealiness, a considerable amount of research has been done since the early 1900's.

The most comprehensive and intensive was that of Sweetman (48). This worker defined the potato tuber as "a dispersion of starch, sugar, cellulose, and protein as constituents, with other components in lesser proportions, such as vitamins, solanin, acids, etc., in a water medium. The starch is in suspension, the cllulose and protein in colloidal solution, and the sugar, ash, and most of the other materials, in true solution. The physical and chemical changes produced by cooking potatoes are of two types,, i.e., those resulting from losses to the cooking medium, (for example, frying fat); and those resulting from the action of heat on the various tuber components; (this includes all the changes which occur in the cooking process)."

Earlier literature reported considerable variance of opinion among workers as to the changes which occurred within a tuber during cooking. Atwater (2) stated that potato mealiness was due to the starch swelling with cooking, followed by subsequent bursting of the cells. East (15) also believed mealiness was due to the presence of sufficient starch to burst the cell walls. These opinions were based on the presence of broken cells after the potatoes had been mashed. Later workers (11, 13, 14, 26, 49) disagreed with these theories, showing that disintegration of the cells was due to the mechanical operation of mashing rather than to the cooking process itself.

Langworthy (26) reported that examination of cooked potatoes, which were mealy in texture, revealed no bursting of the cell walls. She wrote that "the middle lamella which holds the cells together had dissolved and the cells separated from each other." Day (14) also found that even in mealy potatoes cooking was not characterized by bursting of the cell walls. Coudon and Bussard (13) stated that mealy potatoes were simply those which disintegrated during cooking, i.e., the cells of such tubers separated from each other. In non-mealy potatoes this separation did not occur. In neither case was there a bursting of the cell walls. Butler (11) reached the conclusion "that it could be readily determined by direct experimentation that mealiness was due to cellular separation, not to cellular disintegration."

Sweetman (49) further confirmed that cell walls did not burst during cooking. In fact, most of the cell walls maintained their integrity after mechanical treatment sufficient to give a well mashed product. She suggested that to explain relative degrees of mealiness it was necessary to seek the reason for variation in cell separation of the cooked product.

The intensive research of Sweetman on the subject of physico-chemical changes occurring during cooking of potatoes involved a number of factors. These were: solution of pectic substances; gelatinization of starch; softening of cellulose; coagulation of protein; and caramelization of sugar.

This worker (48) showed that when potatoes were cooked, hydrolysis of protopectin and solution of the pectin occurred, with resultant separation of the cell walls. This factor had a tendency to be correlated with mealiness, or texture, but could not be associated with starch content. The reasons advanced were that since pectin held the cells together, mealiness resulted when a large proportion of the pectins were easily soluble or the proportion of insoluble pectins was low. Pectin compounds were believed to be involved in cohesion, the capacity of potatoes to resist disintegration or sloughing when boiled, which was inversely correlated with mealiness. Calcium pectate, a component of the cell wall, seemed inversely associated with sloughing, which occurred in many mealy potatoes when they were boiled, although some lots of mealy potatoes did not slough. Pyke (39) found that the addition of soluble calcium salts to mealy tubers during boiling reduced sloughing and was considered satisfactory for home or small scale usage.

Nutting (34) also reported that the addition of calcium sulfate-sodium chloride tablets to potatoes during cooking reduced sloughing. Soaking uncooked tubers in a strong calcium solution prior to cooking also substantially reduced sloughing. This effect was thought to be due to the calcium salts firming the pectin which held the cells together. Sloughing could be reduced by storage of the tubers at temperatures low enough to decrease the starch content. When tubers were cooked the starch grains swelled, causing distortion of the cell walls. Subsequent sloughing was believed to be due to dissolution of the pectin holding the cell walls together.

Later, Bushnell (10) showed that high calcium content of potato tubers was closely correlated with low fat absorption during frying, high total solids, and starch content. Raw tubers which contained higher percentages of total calcium produced better potato chips, based on color ratings. Tubers differed in chip quality, with those of Russet Burbank best, and Red Pontiac the poorest.

The relationship between pectin and mealiness in potatoes was also investigated by Freeman and Richie (16), who extracted pectin fractions from raw and cooked tubers. They found no consistent relationship between quantity of pectin and mealiness. Mealy tubers, either cooked or raw, did not yield more water soluble pectin than waxy samples. However, these workers explained that a possible reason for these results was the degradation of pectin to soluble forms. This could have taken place during the initial period of cooking before the potato tissue reached a point which could be termed mealy or waxy. Personius and Sharp (37) further confirmed this with studies in which they found that weakening of the cementing materials between the cells took place between 113-167 degrees F. The weakening went so far at each temperature and then stopped, so that in order to weaken the cementing material still further the temperature had to be increased.

More recent work by Potter and McCamb (38) showed no significant difference in pectin content of tubers in the varieties and lots studied. The pectin content of the tubers was independent of specific gravity, and varied with different growing locations and cultural conditions. There was no correlation between subjective appraisal for texture and the pectin content of the tubers. Bettelheim and Sterling (4, 5) found no obviously direct relationship between the characteristics of pectic materials and potato tuber texture. Their results were interpreted as seeming to negate the supposition that cell separation as such was responsible for mealy texture and cell adhesion responsible for waxy texture of potatoes. Starch content of the tubers was believed to be the principal factor determining potato texture by causing a distension of the cell walls during gelatinization, inducing the cells to round off from each other.

Tensile strength was used by Personius and Sharp (37) to study the effect of cooking on the ease of cellular separation in cooked potato tubers. The objective was to determine the minimum of longitudinal stress required to pull a section of potato tuber asunder. However, microscopic examination failed to show a relationship between tensile strength of raw tubers and size of cells, thickness of cell walls, amount of starch in the cells, or size of starch grains. There was also no significant difference established between tensile strength of raw tubers and texture, or mealiness. Cooking the tubers simply decreased the tensile strength to a constant value. No difference was observed between waxy and mealy tubers as to adhesion of cells in the raw or cooked tissue. According to these workers, separation of cells was apparently not dependent on starch gelatinization, since a weakening of the cementing materials between cells occurred at temperatures below the gelatinization temperature of the starch.

Recent research has indicated some correlation between the percentage of starch and dry matter in raw tubers and mealiness ratings of cooked tubers (5), but the exact nature of the relationship has not been determined. Starch has been commonly reported as the principal constituent of the dry matter in potato tubers, along with lesser amounts of sugar, cellulose, and proteins. Consequently, some research has been directed towards establishing correlations between the starch content of tubers and their mealiness ratings. However, despite apparent relationships between these factors, considerable variation has been found in reports on the subject.

According to Sweetman (49), starch was present in potato tuber tissue in the form of microscopic grains, composed of concentric layers of amylose and amylopectin. The outer layer had different properties from the inner bulk of the grain. The former, known as amylopectin, was relatively dense, and, when heated, became slimy and sticky. The inner portion of the grain, termed amylose, was readily dispersed in either hot or cold water to form a colloidal solution.

When uninjured starch grains were mixed with cold water, a non-viscous suspension was formed, the grains swelled slightly, and gradually settled to the bottom. Heating stimulated swelling, and a rapid increase in rate of swelling took place between 50 and 60 degrees C., with a maximum increase occurring at a temperature somewhat below the boiling point. It was estimated that potato starch grains increased forty times in volume during gelatinization, as compared with eight times for the starch grains of wheat.

Reports have shown that amylose and amylopectin differed fundamentally in chain structure (28, 50). Amylose was composed of unbranched chains of molecules, while amylopectin consisted of much branched chains. This type of branching structure gave amylose a more water soluble character, while amylopectin did not exhibit this property. Because of the different physical properties of these two starch components, variations in the relative concentrations of each altered the gelling properties of starch granules, and thus affected mealiness ratings. Some evidence has been presented to show that the gelling properties of starch from different tuber groups varied. Unrau and Nylund (50) have reported that, because of these differences in physical properties, high concentrations of amylose in potato starch conferred greater mealiness while high amylopectin content caused waxiness. Their data on the relationship between amylose content and mealiness of tubers, as assessed by taste panels, seemed to agree with these suppositions. Potato tubers showing the highest mealiness scores, by taste test, also contained the highest percentage of amylose.

Starch content has been found directly proportional to specific gravity (5), but tubers of different varieties, having identical specific gravity, did not necessarily have the same starch content. Although a positive correlation existed between mealiness and starch content, the low mealiness scores of some high specific gravity tubers could not be explained by starch content alone (50). Starch from low specific gravity tubers, however, contained less amylose. Tubers of the Cobbler and Waseca varieties contained more amylose than did Red Pontiac tubers of the same specific gravity. Therefore, mealiness and amylose content seemed positively correlated. Low specific gravity Waseca tubers scored higher in mealiness ratings than low specific gravity Cobbler tubers, and also contained more amylose.

Although starch content appeared to affect the specific gravity of potato tubers, the influence of starch on mealiness ratings varied considerably within tuber samples of different varieties, even at the same specific gravity levels. This was pointed out by Sweetman (49) in studies on the effect of starch gelatinization on mealiness. Barmore (3) showed that starch content was a major factor contributing to mealiness, but also found differences in texture ratings by taste panels even between potatoes with the same starch content. Other factors were believed to contribute to this difference, but no significant correlation was found between mealiness and other constituents of potato tuber tissue. Shewfelt (42) also found starch to be significantly correlated with mealiness or texture, and believed that cell wall thickness of cooked tissue was correlated with mealiness. Bettelheim and Sterling (5) concluded that the relative amount of amylose or amylopectin in different tuber samples was not correlated with texture scores of taste panels. Their opinion was that differences in the amount of amylose or amylopectin present in potato starch had some influence on the mealiness or waxiness of the tuber, but that these differences were not measurable by their technique.

Other characteristics of starch in potato tubers, such as size of the starch grains, were not thought to be correlated with mealiness by

Sweetman (49), nor Unrau and Nylund (51). However, Briant (9) reported a negative correlation between tuber mealiness and the percentage of starch grains below .02 mm. in diameter, indicating that the more of these smaller starch grains in a tuber, the less mealy it was likely to be. This worker concluded that there was no apparent correlation between potato mealiness and the percentage of starch grains above .03 mm. in diameter.

Sharma and Thompson (41) found that the proportion of various sizes of starch grains in potato tubers was related to specific gravity. Tubers having higher percentages of large starch grains (above 75 microns in diameter) were highest in specific gravity. Tubers containing higher percentages of very small starch grains (below 25 microns in diameter) were of lowest specific gravity, while those having intermediate sizes of starch grains showed no consistent differences in specific gravity. These workers theorized that the relative composition of potato starch, i.e., the percentage of small and large starch grains developed under a common environment, might be a varietal characteristic.

The literature contained few reports concerning the effect of cell size on potato quality. Lehmann (27) stated that there was a positive correlation between tuber size and the size of the cells composing the tuber. Large tubers were always made up of larger cells than smaller tubers. Tubers of several potato varieties, grown under similar conditions, showed cell size differences. Tubers of the same variety, grown in different environments, also varied in cell size.

Bredemann and Schulze (8) have reported that the size of potato tuber cells was characteristic for each variety, although tuber cell size was affected by environmental conditions. There was no correlation between cell size and size of starch grains in tubers, nor between size of cells and time of maturity of the tubers. Varieties differed in the percentage of cells and starch grains of different sizes found in the tubers. Tubers of varieties having approximately the same mean cell diameter could be distinguished by the percentage of the various sizes of cells they contained. These results were considered important for potato starch manufacture, since the larger cells yielded more starch.

Some research on the relationship between nitrogenous compounds, protein, and the quality of potato tubers has been reported. The protein of potatoes, according to Sweetman (48), consisted largely of the globulin, tuberin, which was insoluble in water but soluble in dilute solutions of the salts of strong acids and bases. Due to this property most of the potato protein was dispersed in the juice of the tuber. Early workers, such as Coudon and Bussard (13), reported that the ratios of nitrogen and protein-nitrogen to starch were highest for non-mealy tubers and lowest for mealy potatoes. Other workers (15, 20) found that neither nitrogen nor protein-nitrogen was related to quality of potatoes.

Some of the more recent research on this subject was that of Unrau and Nylund (50), who concluded that there was an inverse relationship between crude protein and specific gravity in both raw and boiled tubers. However, no association between protein content and mealiness of the tubers was apparent. Most of the nitrogen was present as small peptides, free amino acids, or nitrogen bases. These data indicated that tuber mealiness was negatively correlated with the amount of nitrogenous materials present, but these workers believed that this association could be significant. The simple nitrogenous compounds could act as "mortar agents" between gelatinized starch grains, or as anti-swelling agents by forming a protective layer around partially gelatinized starch grains.

The sugar content of a potato tuber had a definite effect on its cooking quality. Sweetman (48) pointed out that potato tubers contained varying amounts of sugar from almost none to over five per cent, depending upon storage conditions. Sugar underwent a carmelization during the heating or cooking, manifested by development of a brown color and often an alteration in the flavor of the cooked product. High sugar content imparted a sweet taste to boiled tubers which was considered undesirable by Appleman (1). Sweetman (49) stated that tubers became sweet when stored at any temperature below 40 degrees F. Sugar accumulation was detrimental to tuber flavor, mealiness, and other culinary qualities. Conditioning these potatoes at 70 degrees F. for ten to fourteen days removed accumulated sugars by increasing respiration and/or partially reconverting sugar to starch. Kimbrough (24) showed that the respiration rate of potato tubers increased markedly when the tubers were moved from a low (36 degrees F.) temperature to a higher temperature (71.6 degrees F.). However, after three weeks storage the maximum respiration rate was attained, following which little temperature influence was noticeable.

The prediction of the culinary quality of raw tubers would be of considerable value. Recent research by Heinze (22) showed that dry matter, alcohol insoluble solids, starch content and specific gravity of raw tubers gave reliable quality predictions. Unrau and Nylund (50) also recently concluded that mealiness was negatively correlated with the polysaccharide content of tubers. They suggested that the high percentage of total sugars in Red Pontiac tubers might account for the low specific gravity and mealiness ratings of tubers of this variety. They also believed that high concentrations of sugars and soluble polysaccharides might act in the same manner as the small molecular weight nitrogenous compounds. Although mealiness was apparently negatively correlated with polysaccharide content, low specific gravity Waseca tubers contained approximately the same amount of polysaccharides as Red Pontiac tubers, yet were scored higher in mealiness.

MATERIALS AND METHODS

Tubers of four Irish potato varieties, Red LaSoda, Sebago, White Rose and Russet Burbank, were planted and harvested at a northern and a southern location (Starks Farm, Rinelander, Wisconsin and Ben Hur Farm, Baton Rouge, Louisiana) for this research.

Environmental and cultural conditions were similar for all varieties at a location. Spring and fall crops were grown at Baton Rouge and compared in quality studies with each other and those grown at Rhinelander. Spring and fall crops at Baton Rouge were each harvested on several different dates for quality comparisons.

Fifty to one hundred pounds of potato tubers were obtained from a variety, location, and harvest date. Southern grown potatoes were placed in 70 degrees F. storage immediately following harvest. Northern grown samples were shipped to Baton Rouge and placed in 70 degrees F. storage. All lots remained in 70 degrees F. storage for one month before physical and chemical analyses were made. Tubers from the northern grown seed were used to plant the spring crop at Baton Rouge, while potatoes from the spring crop provided seed for the following fall crop at that location. Potatoes of all varieties were planted on the same date at a location.

Four harvests of both spring and fall crops were made at Baton Rouge. The first harvest was made at the normal commercial harvest period, and succeeding harvests at later intervals.

Sampling and Preparation

Eight pounds of potatoes were selected from each variety for specific gravity and dry matter determinations. Wherever possible, the same tubers were used for physical tests, chemical studies, and organoleptic ratings. Four replications, each consisting of twelve unpeeled tubers, were used for the chemical analyses.

Specific Gravity, Dry Matter

These determinations were made with the potato hydrometer (44). The method utilized an eight pound sample of potato tubers, chosen at random, and placed in a wire basket, suspended from the bulb of the hydrometer. When the sample and apparatus were placed in a container of water the correct specific gravity and dry matter readings could be made directly from the hydrometer.

The specific gravity of tubers used for starch grain and cell size measurements was determined individually by the salt brine solution method.

Organoleptic Tests

The same eight Staff members served on the taste panel throughout these ratings. Samples were set up and analyzed by the method of paired comparisons (7). Panel members were asked to rank the samples in ordinal arrangement of 0 to 4 (mealiest sample = 4, waxiest sample = 0). The criteria used to determine mealiness and waxiness were as described by Sweetman (49). Tubers were baked and served warm, without the addition of table salt or other seasoning.

Anatomical Studies

Some research was undertaken to determine if there were varietal differences in tuber cell size and starch grain size which were associated with mealiness. Tubers grown under similar environmental and cultural conditions at the northern location during 1959 were used.

Anatomical studies were made of tubers of the Irish potato varieties Red LaSoda, Sebago, White Rose, and Russet Burbank. Five tubers of equal size, weight (200 grams), and known specific gravity from each variety were used for cell and starch grain size measurements. Each tuber was cut in half, one-half baked and tested by the taste panel, while the other half was not cooked. Sections were taken from the periderm and cortex of the halves of individual tubers, both cooked and raw. The material was fixed in formalin-propionic acid-alcohol, and dehydrated in tertiary-butyl alcohol. Sections of both raw and cooked tissue were made and stained with fast green and iron hematoxylin. Cells and starch grains from tubers of each variety, both raw and cooked, were measured with a calibrated ocular system. All measurements were made in the parenchymatous tissue of the cortex, 2500 microns beneath the periderm of the tubers. Cell size was expressed as cross-sectional area in square microns.

Starch grains were classified into four size groups: (A) Large (above 75 microns in diameter) (B) Medium (50 to 75 microns in diameter) (c) Small (25 to 50 microns in diameter) (D) Very small (below 25 microns in diameter).

Chemical Determinations

Wherever possible, the same unpeeled tubers used in the specific gravity tests were also used for all chemical analyses and mealiness ratings. This was done to reduce variations in any factors which might be caused by using other tubers for the several determinations. In addition, removal of the skin of the tuber caused a loss of some tuber flesh at the same time. This could result in erroneous readings of some materials, especially starch and amylose. Samples for analyses were obtained with a 9/16 inch cork borer. One longitudinal and one cross-sectional core were taken through the entire tuber. This method allowed a more representative sample from all tuber areas, and tended to mitigate the variations of chemical constituents in different areas of the tuber. The core samples were then used for the chemical procedures, being prepared as necessary.

Total Starch

These analyses were based on the method of Nielsen (32), with some modifications (33). The fresh sample was ground in a Waring Blendor, the starch extracted with 4.0 to 4.8 molar perchloric acid, and the dissolved starch estimated by photoelectric colorimeter readings of the blue color produced with iodine. The use of K55 red filter in the colorimeter for the readings was reported to considerably reduce the error produced by dextrins when present (32).

The percentage of starch was calculated from a standard curve prepared from the colorimeter readings of a known range of starch concentration, using raw starch extracted from potato tubers (32).

Amylose and Amylopectin

The percentage of these starch constituents was estimated colormetrically according to the method of Halick and Keneaster (19), who found a high correlation between their results and cooking tests. This procedure was modified for potatoes and based on the color reaction of amylose with iodine. The intensity of the blue color produced has been reported indicative of the amylose content of various starches (28).

A standard curve for determination of amylose and amylopectin percentages was obtained according to the procedure outlined for this method.

Sugars

Sugar content was determined as outlined by Morell (31). The decrease in yellow color produced by heating sugars with alkaline ferricyanide was measured with a photoelectric colorimeter. Sugar percentages were determined by comparison of readings with a standard reference curve.

Protein and Nitrogen

The analyses for these materials were made according to the procedures described in the Methods of Analysis of the Association of Official Agricultural Chemists (36).

EXPERIMENTAL RESULTS

Specific Gravity

Marked variations in specific gravity existed between tubers of the four varieties. Specific gravity was also influenced by location, growing season, and date of harvest (Tables 1, 2, and 4).

All potatoes from the northern location were higher in specific gravity than those grown during the spring or fall at the southern location (Table 1). Tubers produced during the fall were of higher specific gravity than those from the spring crop at the southern location.

Russet Burbank tubers were highest in specific gravity, while those of the Red LaSoda variety had the lowest specific gravity. White Rose and Sebago potatoes were at an intermediate specific gravity level.

In general, the specific gravity of potatoes produced in the spring under Louisiana conditions decreased as harvest dates were extended (Table 2). However, the reverse occurred in fall potatoes grown under Louisiana conditions. Specific gravity of tubers increased with delayed fall harvest dates (Figs. 2, 3, 4, 5).

Tables 3 and 4 show that a significant relationship existed between specific gravity and cell size of tubers grown at the northern location during 1959. Of the four varieties, Red LaSoda tubers were composed of the smallest cells, while those of the Russet Burbank were made up of

Table 1. The effect of variety, season, and location on the specific gravity, mealiness, starch and amylose content of potato tubers.

Variety	Specific Gravity	Mealiness Rating*	% Total Starch	% Amylose
		La. Spring Crops (1958 and 1959)		
Red LaSoda	1.052	1.27	12.5	6.4
Sebago	1.053	1.43	12.9	7.8
White Rose	1.055	1.74	13.3	8.2
Russet Burbank	1.064	2.53	15.2	9.2
		La. Fall Crop (1958)		
Red LaSoda	1.068	2.00	14.8	7.5
Sebago	1.069	1.25	15.5	11.8
White Rose	1.067	1.75	15.7	8.4
Russet Burbank	1.070	2.65	17.5	10.0
		Northern Crops (1957 and 1958)		
Red LaSoda	1.070	1.02	13.2	10.0
Sebago	1.074	1.40	13.4	11.8
White Rose	1.073	1.60	13.9	12.8
Russet Burbank	1.091	2.77	18.9	18.7
		Av. of All Crop Seasons		
Red LaSoda	1.063	1.43	13.5	8.0
Sebago	1.065	1.36	13.9	10.5
White Rose	1.065	1.70	14.3	9.8
Russet Burbank	1.075	2.65	17.2	12.6

*Mealiness Scale - 0 = Waxy
1 = Sl. waxy
2 = Sl. mealy
3 = Mealy
4 = V. mealy

Table 2. The effect of variety, season, and harvest date on the specific gravity, mealiness, starch and amylose content of potato tubers.

		La. Spring Grown Crops-(1958 and 1959)				La. Fall Grown Crop (1959)			
Variety	Harvest Date**	Specific Gravity	Mealiness Rating*	% Total Starch	% Amylose	Specific Gravity	Mealiness Rating*	% Total Starch	% Amylose
Red LaSoda	1	1.055	1.71	13.0	8.0	1.062	2.00	13.5	4.8
	2	1.057	1.00	12.6	7.6	1.067	1.80	14.8	8.4
	3	1.048	-	-	5.2	1.070	-	-	8.8
	4	1.048	1.10	12.0	4.6	1.073	2.20	16.1	7.8
	Average	1.052	1.27	12.5	6.4	1.068	2.00	14.8	7.6
Sebago	1	1.054	1.86	12.0	8.7	1.068	1.25	14.1	10.2
	2	1.057	1.00	13.6	9.2	1.071	1.00	15.5	14.9
	3	1.050	-	-	6.4	1.072	-	-	13.2
	4	1.050	1.43	13.0	6.7	1.065	1.50	16.9	8.8
	Average	1.053	1.43	12.9	7.8	1.069	1.25	15.5	11.8
White Rose	1	1.055	2.00	13.7	8.6	1.058	1.75	14.3	6.0
	2	1.055	1.57	14.1	9.0	1.075	1.50	15.7	10.5
	3	1.056	-	-	7.6	1.074	-	-	9.8
	4	1.055	1.65	12.0	7.4	1.061	2.00	17.1	7.3
	Average	1.055	1.74	13.3	8.2	1.067	1.75	15.7	8.4
Russet Burbank	1	1.065	3.14	16.2	9.8	1.064	2.65	16.8	6.9
	2	1.067	1.86	14.9	10.0	1.072	2.00	17.5	11.5
	3	1.060	-	-	7.4	1.071	-	-	10.4
	4	1.063	2.57	14.5	9.5	1.071	3.30	18.2	11.2
	Average	1.064	2.53	15.2	9.2	1.070	2.65	17.5	10.0

(Spring)	Harvest Dates**	(Fall)
May 30	- 1 -	Nov. 12
June 12	- 2 -	Nov. 24
June 26	- 3 -	Dec. 3
July 10	- 4 -	Dec. 12

*Mealiness Rating:
0 = Waxy
1 = Sl. waxy
2 = Sl. mealy
3 = Mealy
4 = V. mealy

Table 3. Relationship between specific gravity and cell size of northern grown tubers (1959 crop).

Variety	Specific Gravity	Av. Cross-Sectional Area of Cells (Sq. Mic.)
	1.070	9,170
	1.075	8,050
Red LaSoda	1.072	9,450
	1.073	9,590
	1.072	7,770
	1.065	11,480
	1.067	8,960
White Rose	1.070	10,220
	1.063	9,800
	1.060	9,660
	1.080	12,740
	1.070	10,780
Sebago	1.075	11,760
	1.070	10,990
	1.068	12,250
	1.085	16,520
	1.070	13,020
Russet Burbank	1.073	15,540
	1.080	16,170
	1.080	16,730

r = .510*

(*-Significant at the 5% level)

Table 4. Effect of variety on quality of northern grown potato tubers (1959 crop).

Variety	Specific Gravity	Mealiness Rating*	Av. Cross-Sectional Area of Cells (Sq. Microns)** Raw Tubers	Baked Tubers	% Starch *** Grains Above 50 Mic. Dia.	% Amylose	% Total Starch
Red LaSoda	1.072	1.14	8,787	13,217	1.5	8.1	10.8
White Rose	1.065	1.31	10,218	15,148	2.3	8.0	12.1
Sebago	1.073	1.61	11,771	18,325	5.6	8.2	14.2
Russet Burbank	1.080	2.68	15,594	25,268	19.4	13.1	18.9

*Mealiness Scale: 0 = Waxy
1 = Sl. waxy
2 = Sl. mealy
3 = Mealy
4 = V. mealy

** -Av. of 10,000 measurements

***-Av. of 2,000 measurements

the largest cells (Fig. 25). Cells of raw tubers of the Russet Burbank variety averaged 89% larger in cross-sectional area than those of Red LaSoda, 53% larger than White Rose, and 32% larger than Sebago tubers.

As shown in Table 5, there was a high degree of correlation between specific gravity and per cent total starch. Tubers of the Russet Burbank variety contained the highest percentage of total starch in all cases. The Red LaSoda potatoes ranked lowest in per cent total starch (Fig. 6).

Mealiness Ratings of Taste Panels

Mealiness ratings of cooked tubers varied with varieties, location grown, and harvest season.

Potatoes grown at the southern location in the fall were rated highest in mealiness. Tubers from Wisconsin and those produced at Baton Rouge in the spring were of approximately equal mealiness. The samples from the northern location in 1957 were higher in mealiness than all others, but those grown there in 1958 ranked considerably lower. These comparisons are shown in Table 1 and Figure 8.

Russet Burbank potatoes were of highest mealiness in all cases. Those of the Red LaSoda variety were lowest, except for the Louisiana fall crop of 1958 (Table 1).

Taste panel ratings in Table 2 point out that the mealiness of tubers grown during the spring in Louisiana decreased with successive harvest dates. The reverse occurred in fall crop harvests at that

Table 5. Relationship between total starch content and specific gravity of tubers (Av. of all varieties, locations, and seasons).

Variety	Per Cent Total Starch	Specific Gravity
	12.0	1.048
	12.0	1.052
Red LaSoda	12.0	1.057
	12.6	1.059
	13.0	1.050
	13.0	1.050
	13.2	1.072
Sebago	13.4	1.079
	13.6	1.059
	13.7	1.056
	13.9	1.075
	14.1	1.050
White Rose	14.5	1.055
	14.8	1.062
	14.9	1.072
	15.5	1.068
	15.7	1.058
Russet Burbank	16.2	1.070
	17.5	1.064
	18.9	1.095

r = .613**

(**-Significant at the 1% level)

location. Tubers from the last fall harvest ranked higher in mealiness than those from the first harvest.

A comparison of mealiness ratings and specific gravity readings of potatoes grown at the southern location during the spring showed a highly significant relationship (Table 6, Fig. 8). No correlation between these factors was found in tubers from the other location or crop seasons.

Mealiness ratings and the total starch content of tubers (Table 7) were significantly related. Potatoes of the Russet Burbank variety rated highest in both respects, while those of the Red LaSoda were lowest (Fig. 11).

Total Starch Content

There were fluctuations in the total starch content of raw tubers of the four varieties grown at the two locations and harvested at different seasons in one location.

All potatoes from the fall crop in Louisiana were highest in per cent total starch, as shown in Table 1. Those grown at the Wisconsin location averaged next highest, while spring crop tubers at the southern location were lowest in per cent total starch.

Tubers of the Russet Burbank variety were higher in total starch content than those of the other varieties (Tables 1 and 4, Fig. 14), while Red LaSoda ranked lowest.

The per cent total starch in tubers of all varieties except Sebago

Table 6. Relationship between the specific gravity and mealiness of Louisiana spring grown potatoes.

Variety	Specific Gravity	Mealiness Rating 1/
	1.055	1.71
Red LaSoda	1.057	1.00
	1.048	1.10
	1.054	1.86
Sebago	1.057	1.00
	1.050	1.43
	1.055	2.00
White Rose	1.055	1.57
	1.056	1.65
	1.065	3.14
Russet Burbank	1.067	1.86
	1.062	2.57

$r = .720^{**}$

(**-Significant at the 1% level)

1/ Mealiness Scale

0 = Waxy　　2 = Sl. mealy
1 = Sl. waxy　　3 = Mealy
4 = V. mealy

Table 7. Relationship between the total starch content and mealiness of tubers (Av. of all varieties, locations, and seasons).

Variety	Per Cent Total Starch	Mealiness Rating[1]
	12.6	1.00
	13.0	1.71
Red LaSoda	13.2	0.90
	13.6	1.00
	13.4	1.30
	13.9	1.45
Sebago	14.9	1.86
	15.5	1.25
	12.0	1.86
	13.7	2.00
White Rose	14.1	1.57
	15.7	1.75
	14.8	2.00
	16.2	3.14
Russet Burbank	17.5	2.65
	18.9	2.15

r = .597*

(*-Significant at the 5% level)

[1] Mealiness Scale

0 = Waxy 2 = Sl. mealy
1 = Sl. waxy 3 = Mealy
4 = V. mealy

(Table 2) decreased as harvest was delayed in the Louisiana spring crops. Delay of harvest in the fall at this location caused an increased starch content of the tubers.

There was a highly significant relationship between per cent total starch and per cent amylose in raw tubers of all varieties (Table 9, Fig. 14), regardless of location grown or season harvested.

Amylose Content

Amylose content of raw tubers was influenced by variety, location, and season of harvest.

Tubers grown at the Wisconsin location (Table 1) averaged highest in per cent amylose. Louisiana fall grown potatoes contained the next highest amount of amylose, while those produced in the spring at this location were lowest in amylose.

The per cent amylose in tubers of all varieties grown during the spring at Baton Rouge decreased as harvest was delayed. An increased percentage of amylose was found in tubers from the fall crop at that location when the harvest date was delayed (Table 2, Figs. 17, 18, 19, 20).

Russet Burbank potatoes contained the highest percentage of amylose under all conditions, while those of Red LaSoda had the lowest (Fig. 1, Table 1).

The amount of amylose in tubers from the southern grown spring and fall crops of 1958 varied significantly between varieties (Tables 12 and 13). Harvest date had a highly significant effect on amylose content.

Table 8. Relationship between the amylose content and mealiness of tubers (Av. of all varieties, locations, and seasons).

Variety	Amylose	Mealiness Rating 1/
	5.3	1.71
	5.6	1.00
	7.1	1.00
Red LaSoda	7.7	1.10
	8.0	0.90
	12.0	1.13
	8.0	1.86
	8.7	1.43
	11.5	1.30
Sebago	11.5	1.45
	11.8	1.25
	12.0	1.50
	6.3	1.86
	7.0	1.57
	7.0	2.00
White Rose	7.5	2.00
	8.4	1.75
	9.2	1.65
	9.6	3.14
	9.8	2.57
	10.0	2.65
Russet Burbank	14.0	1.75
	17.4	2.15
	20.0	3.38

r = .424*

(*-Significant at the 5% level)

1/ Mealiness Scale

0 = Waxy 2 = Sl. mealy
1 - Sl. waxy 3 = Mealy
4 = V. mealy

Table 9. Relationship between the total starch and amylose content of raw tubers (Av. of all varieties, locations, and seasons).

Variety	Per Cent Total Starch	Per Cent Amylose
	12.0	4.5
	12.6	5.6
Red LaSoda	13.0	5.3
	13.2	8.0
	14.8	7.5
	12.0	6.3
	13.0	6.9
Sebago	13.4	11.5
	13.6	7.1
	15.5	11.8
	12.0	4.5
	13.7	7.0
White Rose	13.9	11.5
	14.1	7.0
	15.7	8.0
	14.5	7.1
	14.9	8.0
Russet Burbank	16.2	9.6
	17.5	10.0
	18.9	17.4

r = .769**

(**-Significant at the 1% level)

There was also a significant interaction between varieties and harvest dates.

Table 8 and Figure 12 show that a correlation existed between per cent amylose and mealiness ratings of tubers from all crops. A highly significant relationship between per cent amylose and specific gravity of the tubers was also found (Fig. 1).

Cell Size

A comparison of the cell size in raw and cooked tubers showed varietal influences. There were relationships between this factor and some others.

Cooked and raw tubers of the Russet Burbank variety contained the largest cells, and Red LaSoda the smallest (Table 4, Fig. 24).

A highly significant relationship (Table 10) existed between cell size and per cent total starch in the tubers grown at Wisconsin during 1959. These associations are further shown in Figures 15, 21, and 22.

No correlation (Figs. 9, 10, 21) was found between cell size and mealiness ratings of tubers, nor between cell size and per cent amylose.

Starch Grain Size

Differences in starch grain size were noted in tubers grown at Wisconsin during 1959. Some interrelationships were also observed.

There was no significant association between the percentage of starch grains below fifty microns in diameter and specific gravity,

Table 10. Relationship between the total starch content and cell size of raw and cooked tubers of different varieties grown at Rhinelander, Wisconsin (1959 crop).

Variety	Per Cent Total Starch 1/	Av. Cross-Sectional Area of Raw Cells 2/ (Sq. Microns) 3/	Av. Cross-Sectional Area of Cooked Cells (Sq. Microns) 4/
Red LaSoda	10.8	8,787	13,217
White Rose	12.1	10,218	15,148
Sebago	14.2	11,771	18,325
Russet Burbank	18.9	15,594	25,268

1/Av. of 8 analyses

2/Av. of 10,000 measurements

3/r = .998**

4/r = .999**

(**-Significant at the 1% level)

Table 11. Relationship between starch grain size and total starch content of tubers of different varieties grown at Rhinelander, Wisconsin (1959 crop).

Variety	Per Cent Total Starch 1/	Per Cent Starch Grains Above 50 Microns in Diameter 2/
Red LaSoda	10.8	1.5
White Rose	12.1	2.3
Sebago	14.2	5.6
Russet Burbank	18.9	19.1

r = .978*

(*-Significant at the 5% level)

1/Av. of 8 analyses

2/Av. of 2,000 measurements

Table 12. Analysis of variance summary table for the amylose content of tubers of different varieties grown in the spring of 1958 at the Louisiana location.

Source of Variation	Degrees of Freedom	Mean Square	F Values
Main Plots:			
Varieties	3	12.66	13.05**
Blocks	3	3.42	3.52
Error (a)	9	0.97	-
Sub Plots:			
Harvest Date	3	76.29	42.86**
Variety x H. Date	9	5.04	2.83*
Error (b)	36	1.78	-

(* -Significant at the 5% level)

(**-Significant at the 1% level)

Table 13. Analysis of variance summary table for the amylose content of tubers of different varieties grown in the fall of 1958 at the Louisiana location.

Source of Variation	Degrees of Freedom	Mean Square	F Values
Main Plots:			
Varieties	3	55.94	17.58**
Blocks	3	1.37	0.43
Error (a)	9	3.19	-
Sub Plots:			
Harvest Date	3	63.97	13.61**
Variety x H. Date	9	6.01	1.27
Error (b)	36	4.70	-

(**-Significant at the 1% level)

mealiness, cell size, or starch and amylose content of the tubers. However, the per cent starch grains above fifty microns in diameter was correlated with some of these tuber factors.

Russet Burbank potatoes (Table 4) contained the highest percentage of starch grains above fifty microns in diameter, and Red LaSoda the lowest amount.

A comparison of the per cent starch grains above fifty microns in diameter and the amount of total starch contained in tubers showed a correlation (Table 11). Figure 16 further illustrates this relationship.

The per cent amylose and the cell size of the tubers were also related to the percentage of starch grains above fifty microns in diameter (Figs. 23, 26).

No relationship was found between the percentage of starch grains above fifty microns in diameter and the specific gravity or mealiness ratings of the tubers (Figs. 7 and 13).

DISCUSSION

Differences in specific gravity of tubers reported herein generally agree with other work (25, 42, 46, 47), and indicate that specific gravity is of value as a measure of potato culinary quality. However, it is important to note that associations between specific gravity and mealiness ratings of tubers fluctuated, except at the varietal extremes of Russet Burbank and Red LaSoda. There was no consistency in the mealiness ratings of Sebago and White Rose potatoes, nor in their specific gravity. A correlation between these two factors was found in Louisiana spring grown tubers, but none existed in the fall crop potatoes at that location, nor those produced at Wisconsin.

The higher specific gravity of tubers grown at the norther location was expected. Relatively high temperatures in Louisiana during the spring growing season are not favorable for accumulation of dry matter in the tubers, due to high respiration rates at that time. However, the specific gravity and mealiness of the southern fall grown tubers compared favorably with that of the Wisconsin crops. Potatoes from the Baton Rouge location in the fall were superior in mealiness to those grown in Wisconsin, and of higher specific gravity and mealiness than tubers from the Louisiana spring crop.

Contrasting specific gravity of potatoes from delayed harvests in the spring and fall at Baton Rouge points out the influence of temperature on total dry matter content. Delay of spring harvest, while the temperature increased, resulted in a lower specific gravity of the tubers. Those from the fall crop, however, were higher in specific gravity as harvest was delayed and temperature decreased, causing lower respiration rates.

The specific gravity-cell size relationship of tubers was interesting. Literature reviewed contained no reference to this association, although potato tuber cell size and starch grain size failed to correlate (8). Specific gravity and dry matter content of tubers are closely related (25, 29), and starch content has been reported as directly proportional to specific gravity (3, 49). However, tubers of different varieties, with identical specific gravity, did not necessarily have the same starch content. It was also stated (21) that specific gravity did not correctly indicate the starch content, nor by inference the mealiness of potatoes. The work reported here shows that a significant relationship existed between specific gravity and cell size of the tubers, and also starch content and specific gravity. Consequently, it would seem that the relationship between cell size and starch content did influence specific gravity. A significant association was found between total starch and amylose content and mealiness ratings of tubers in all cases, but a correlation between specific gravity and mealiness existed only in tubers grown at Baton Rouge during the spring.

The lack of statistical significance between mealiness ratings and some tuber constituents further emphasizes the need for a more objective method of quality evaluation, as has been stated (49). Variance in mealiness ratings of tubers having the same specific gravity, starch, and dry matter content seems principally due to the subjective nature of the taste panel method of quality comparison.

A further discrepancy in the use of specific gravity-mealiness associations as tuber quality criteria is shown by a comparison of these factors in potatoes grown at Wisconsin during 1957 and 1958. Samples from the 1957 crop were rated higher in mealiness than those grown during 1958, yet the specific gravity of tubers from each variety in 1957 was lower than in the 1958 crop. However, the higher mealiness rankings of the tubers from the former crop may be explained by their higher starch and amylose content. There was a significant relationship between mealiness ratings and the per cent total starch and amylose in these potatoes.

Mealiness scores and amylose content of potatoes produced in Wisconsin during 1957 averaged highest of all crops, while those grown at Baton Rouge during the spring were lowest in both respects. Russet Burbank tubers consistently ranked highest in mealiness and per cent amylose, while the reverse was invariably true of the Red LaSoda potatoes. This would seem to indicate that the amylose content had some influence on mealiness evaluations of the taste panel. Ratings of the tubers of all varieties in respect to these factors, averaged over all crop seasons and locations, show that a correlation did exist.

The decrease in amylose content of Louisiana spring grown tubers, and increased per cent amylose of those from the fall crop there, as harvest was delayed, follow similar patterns in mealiness ratings and starch content. Apparently, increasing respiration rates in the spring crop, as temperature increased, caused a decrease in the amount of amylose in the tubers. The cooler temperatures resulting from delayed fall harvest were responsible for an opposite effect. Lower mealiness ratings of tubers as spring harvest was delayed, and higher mealiness scores of samples from delayed fall harvests, show that the per cent amylose in the potatoes had some influence on taste panel ratings.

The significance between the percentage of amylose and most other factors in tubers grown under all conditions of this study suggests that an amylose analysis would be a more objective method of culinary quality rating than specific gravity or taste panels. Although the work reported here was necessarily limited to four potato varieties, amylose determinations and quality comparisons were made with tubers of many other varieties and seedlings. Associations found between per cent amylose and starch content, mealiness scores, specific gravity and dry matter percentage of these potatoes were similar to those reported herein. The amylose test used was simple and rapid, requiring only a small sample (19). Agreement of results with other methods (28) was good, affording quick comparison of a large number of tuber samples.

Per cent total starch in tubers from the delayed spring and fall harvests followed a trend similar to that of amylose and specific gravity. Starch content decreased in the spring and increased during the fall at Baton Rouge. Since there was a high degree of correlation between the amylose and total starch content of the tubers, this similarity seemed logical. It has been reported that a significant relationship existed between mealiness ratings and per cent starch found in the tubers (5, 42, 50). However, some workers (50) have pointed out that mealiness scores could not be explained by starch content alone. The starch from potatoes ranking low in mealiness also contained less amylose.

Environmental and varietal differences seemed to affect the total starch and amylose content of tubers. Potatoes of the same variety grown at both locations varied as much in per cent starch and amylose as those of different varieties at the same location. The influence of both these tuber constituents on mealiness ratings and specific gravity is shown by the significant associations which existed between them. Total starch and amylose percentages were correlated with taste scores and specific gravity of potato tubers. Potatoes of the four varieties also showed inherent differences in per cent starch and amylose. Russet Burbank tubers from Louisiana and Wisconsin consistently ranked highest; Red LaSoda lowest in total starch and amylose. Sebago and White Rose potatoes, of intermediate rating, maintained this relationship at both locations regardless of season.

Inherent varietal differences reported here indicate that the amylose content of tubers should be considered in a breeding program to improve the culinary quality of southern grown Irish potatoes. Studies to determine the method of ineritance of high amylose content in tubers, and combining of parents possessing this quality, could result in progeny superior to present varieties in this respect. Use of the rapid amylose test (19) in conjunction with a breeding program would be of value in allowing quick screening of seedling tubers for per cent amylose, particularly since only a small sample is required.

Further evidence that the starch content of tubers influenced their mealiness is demonstrated by a comparison of these factors in the northern and Louisiana fall crops. Potatoes at the southern location in the fall averaged highest in both respects, and northern crop tubers ranked next. Samples grown at Wisconsin in 1957 were of higher mealiness and contained more starch than all others, but those from that location in 1958 fell considerably lower in ratings. The former crop season at the northern location was more favorable for production of tubers of high culinary quality than the latter. It should also be pointed out that the last two fall harvests in Louisiana were delayed somewhat beyond the normal date, so that temperatures were lower than would have been the case in the usual fall harvest. In addition, the first killing frost that year had not occurred before the last harvest date of December 12. The average date of the first killing frost in the fall at that location is November 21.

The high quality ratings of Louisiana fall potatoes indicate that perhaps similar results could be expected in spring grown tubers at that location if the crop were planted earlier than now practiced. The potatoes would be grown when conditions might be more favorable for a higher percentage of amylose and total starch to accumulate in the tubers. Earlier planting would increase the risk of frost damage, but could be minimized by cultural practices, and permit maturity of better quality tubers. This is especially important if the crop is being grown for processing, such as potato chip manufacture.

Starch content of tubers seems to be the principal factor determining their cell size, since a highly significant relationship existed between these two factors in the 1959 northern crop. Russet Burbank potatoes had the largest cells, and highest amount of starch, while the reverse was true of Red LaSoda. White Rose tubers had slightly larger cells than Red LaSoda and a higher per cent starch, while Sebago tubers were exceeded only by Russet Burbank in both respects. A varietal trend has been reported (8, 27) in the cell size-starch content association.

Preliminary examination of southern grown tubers of these varieties indicates that they follow a pattern similar to northern potatoes. The lower starch content of Louisiana spring grown tubers is associated with smaller cells than potatoes produced in Wisconsin.

These correlations seem logical, since starch is the principal component of dry matter in potatoes, so larger cells should be necessary to contain higher percentages of starch. The significant association between cell size and specific gravity also indicates that larger cells are required in tubers which contain more dry matter. These findings are based on work with tubers of equal size and weight, as there is some belief (27) that larger tubers are composed of larger cells than smaller potatoes.

Although no significance was found between tuber cell size and mealiness ratings, there was a definite trend towards such an association. Since total starch percentage and cell size of potatoes were highly correlated, and starch content and mealiness scores of tubers were also significantly related, it would seem reasonable that cell size could also influence potato texture. It is possible that the tubers with larger cells, containing more total starch and amylose than those of smaller cell size, were ranked higher in mealiness by the panel due to the more granular taste of the larger cells. This possibility seems even more definite if tuber cell size and mealiness ratings are studied more closely. The cell size of tubers from each variety exactly parallels their mealiness ratings. Russet Burbank ranked first in both respects, Sebago second, White Rose third, and Red LaSoda last. This relationship was also found in potatoes of the same varieties grown in Louisiana during the spring.

The percentage of starch grains above fifty microns in diameter was correlated with cell size, total starch and amylose content of tubers. These relationships may have also influenced taste ratings, even though no direct association existed between starch grain size and mealiness ratings of tubers. Larger starch grains may be necessary in a tuber in order for it to contain higher amounts of starch and amylose. Larger cells could also be required where such starch grains are present.

The lack of significance between per cent starch grains below fifty microns in diameter and other tuber constituents seems to indicate such a relationship, despite the fact that smaller starch grains were more numerous in tuber cells than the larger ones.

Inherent varietal and environmental differences in starch grain size of tubers grown at the northern and southern locations seemed to exist. These characteristics of potatoes have been reported (8, 42). The study related herein shows that Russet Burbank tubers, higher in amylose and starch content, invariably contained the largest percentage of starch grains above fifty microns in diameter. The reverse situation was found in potatoes of the Red LaSoda variety in all cases, while Sebago and White Rose ranked intermediate. Preliminary examination of tubers from these varieties grown in Louisiana during the spring indicates their starch grain size may be smaller than that of potatoes produced in Wisconsin.

All results reported here were obtained with tubers of four Irish potato varieties, from two locations. These data may not be applicable to other varieties and locations.

SUMMARY

Culinary quality comparisons were made with tubers of the Irish potato varieties Red LaSoda, Sebago, White Rose, and Russet Burbank grown at a northern and a southern location.

Specific gravity and mealiness were significantly correlated in tubers grown at the southern location during the spring. Inherent varietal differences in specific gravity were found. Russet Burbank potatoes were highest, and Red LaSoda tubers lowest in specific gravity. Environmental effects on specific gravity were noted. Tubers grown at the northern location were highest in specific gravity, those from the southern location in the spring lowest, and southern fall grown potatoes of intermediate specific gravity. Delay of spring harvest caused a lower specific gravity, while the reverse was true in the fall tubers. Specific gravity of potatoes was also influenced by their cell size and starch content.

There was a significant relationship between mealiness ratings and the per cent amylose and total starch in potatoes. Amylose and total starch content were also highly correlated. Mealiness scores and amylose content of Wisconsin grown potatoes averaged highest, while Louisiana spring grown tubers ranked lowest in these respects. Amylose content and mealiness of tubers decreased as harvest was delayed at the southern location during the spring, while the reverse occurred as fall

harvests in Louisiana were delayed. Varietal, as well as environmental differences were found in amylose content and mealiness of potatoes. Russet Burbank tubers consistently ranked highest in these factors, while Red LaSoda was invariably rated lowest.

Amylose content of tubers appeared to be a more objective method of predicting quality than either specific gravity or taste panel methods.

Inherent varietal differences reported here also indicate that the amylose content of tubers should be considered in a breeding program to improve the culinary quality of southern grown Irish potatoes. The amylose test could be used in conjunction with a breeding program, allowing rapid screening of progeny for the amount of amylose which they contain.

Environmental and varietal differences also affected the total starch content of tubers. Potatoes grown at the southern location in the fall ranked highest in per cent starch, those at that location in the spring lowest, and northern grown tubers intermediate. The starch content of tubers decreased during successive harvests in Louisiana during the spring, while delay of fall harvests there had the opposite effect. Inherent varietal differences in total starch content also existed. Russet Burbank tubers were consistently higher in starch, while Red LaSoda rated lowest.

Tuber cell size and starch content were highly correlated, showing that starch may be the principal determining factor in cell size. Varietal differences in tuber cell size were found, with Russet Burbank containing the largest cells and Red LaSoda the smallest. White Rose cells were slightly larger than those of Red LaSoda, while Sebago cell size was exceeded only by that of Russet Burbank. Indications were that similar trends existed in tubers of the same varieties grown at the southern location, so environmental effects could also influence cell size. There was a definite tendency towards an association between cell size and mealiness ratings of tubers.

The percentage of starch grains above fifty microns in diameter was correlated with cell size, total starch and amylose content of tubers. Inherent varietal differences in starch grain size also existed. Russet Burbank tubers contained the largest amount of starch grains above fifty microns in diameter, and Red LaSoda the lowest, whether grown at the northern or southern location. Environmental influences on starch grain size also seemed to exist.

All results were obtained with tubers of four varieties, at two locations, and may not apply to other varieties and locations.

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APPENDIX

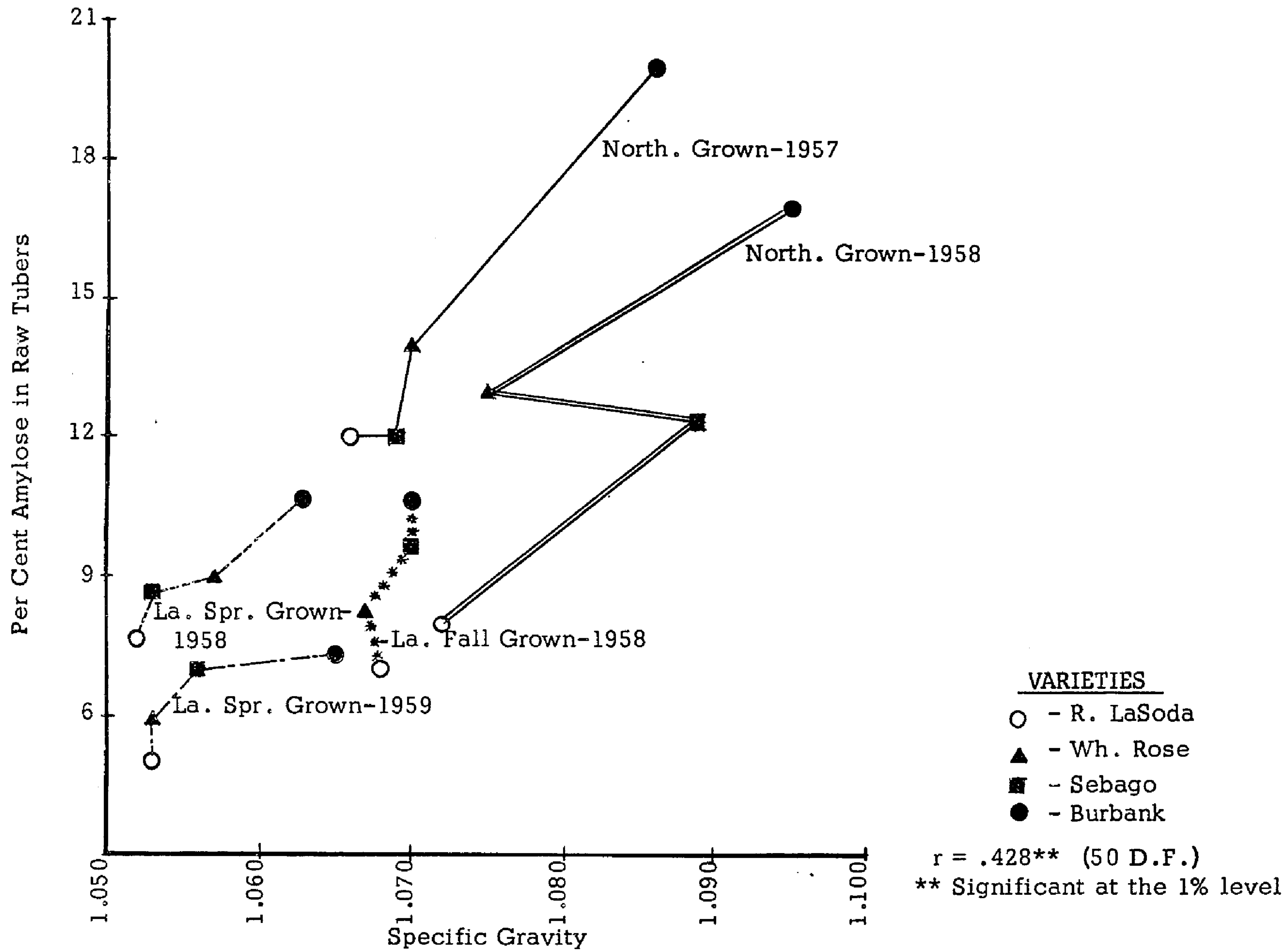

Figure 1. The effect of variety, location, and season on specific gravity and amylose content of potato tubers.

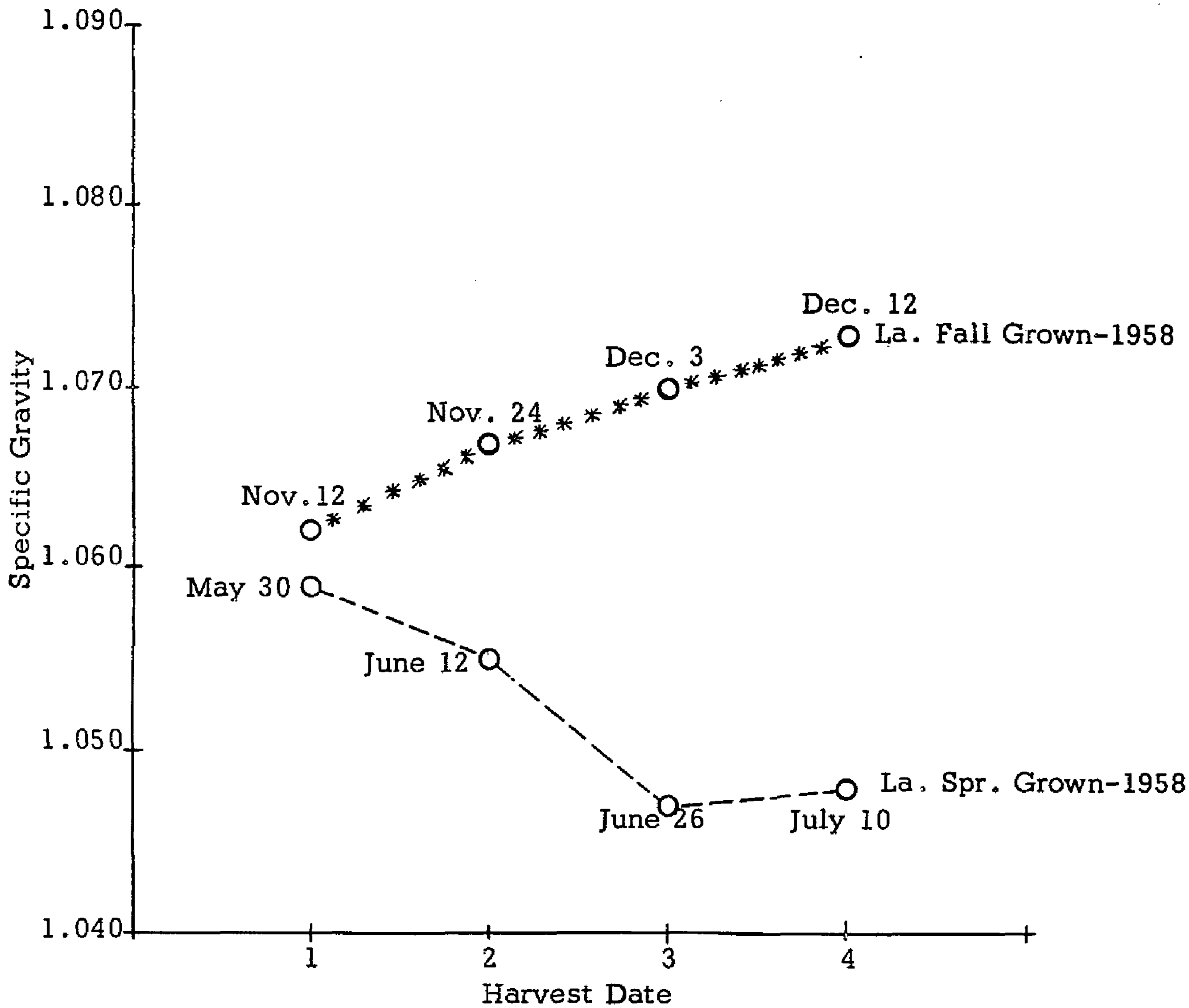

Figure 2. The effect of growing season and date of harvest on the specific gravity of Red LaSoda tubers.

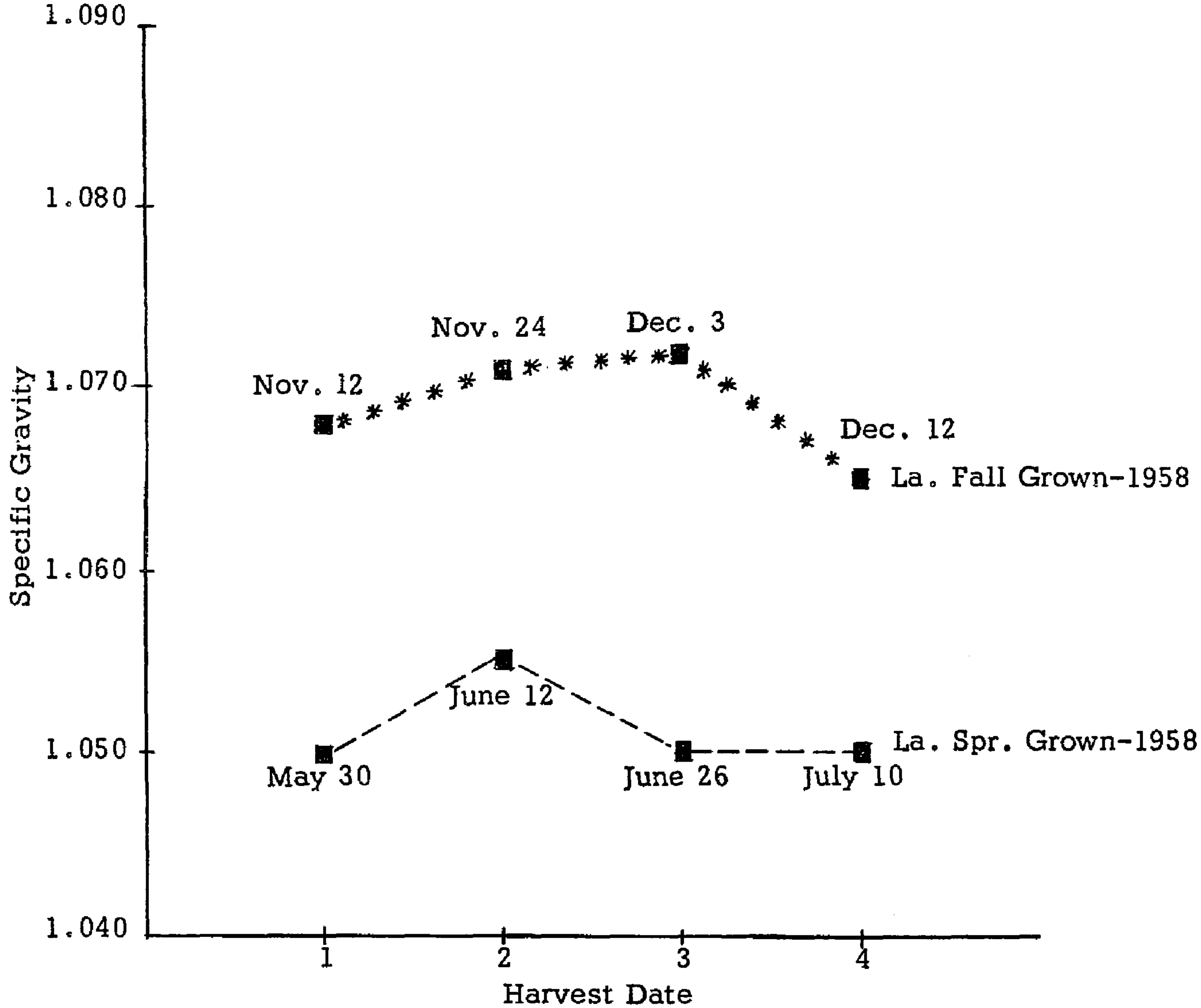

Figure 3. The effect of growing season and date of harvest on the specific gravity of Sebago tubers.

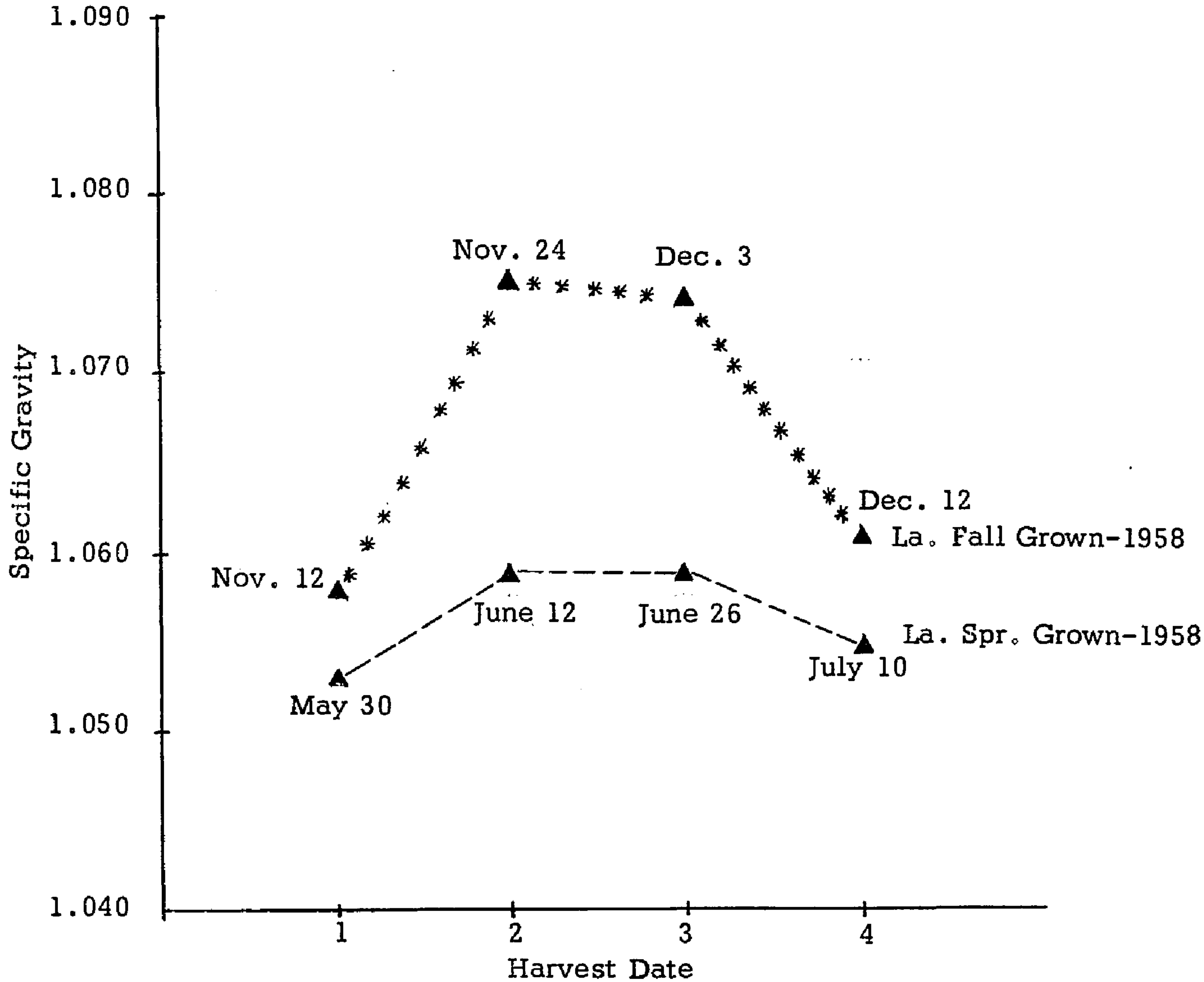

Figure 4. The effect of growing season and date of harvest on the specific gravity of White Rose tubers.

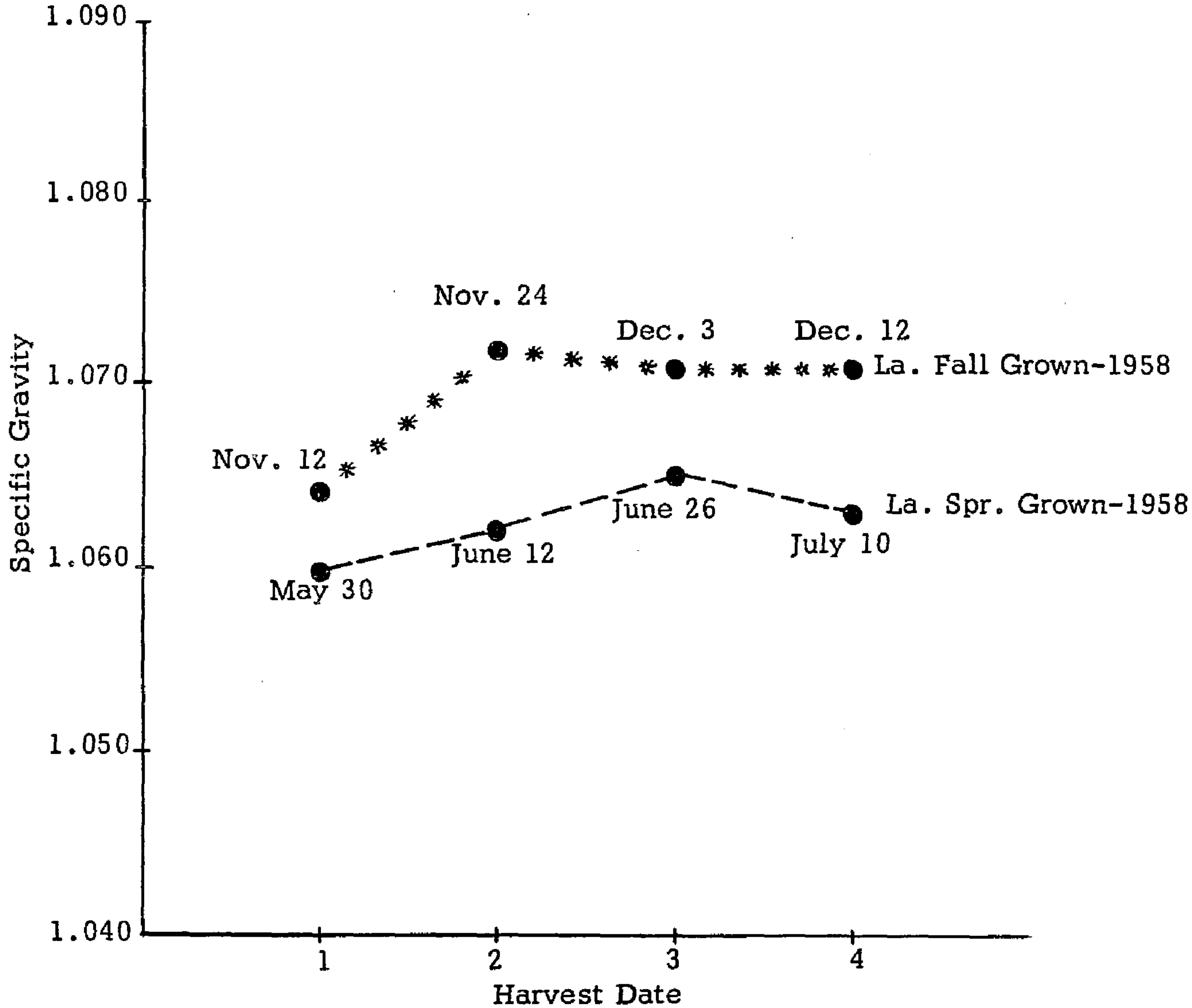

Figure 5. The effect of growing season and date of harvest on the specific gravity of Russet Burbank tubers.

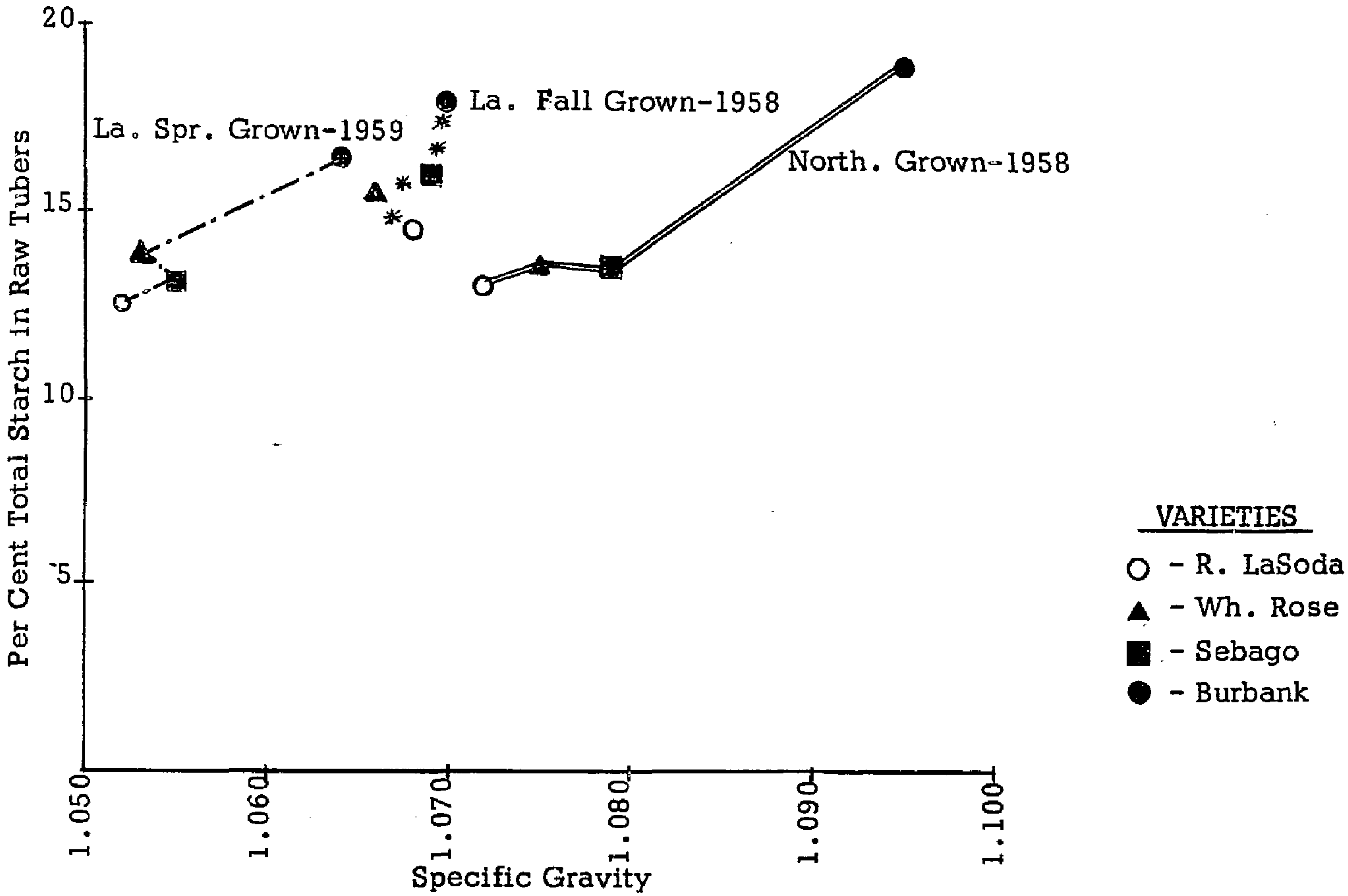

Figure 6. The effect of variety, season, and location on the specific gravity and starch content in potato tubers.

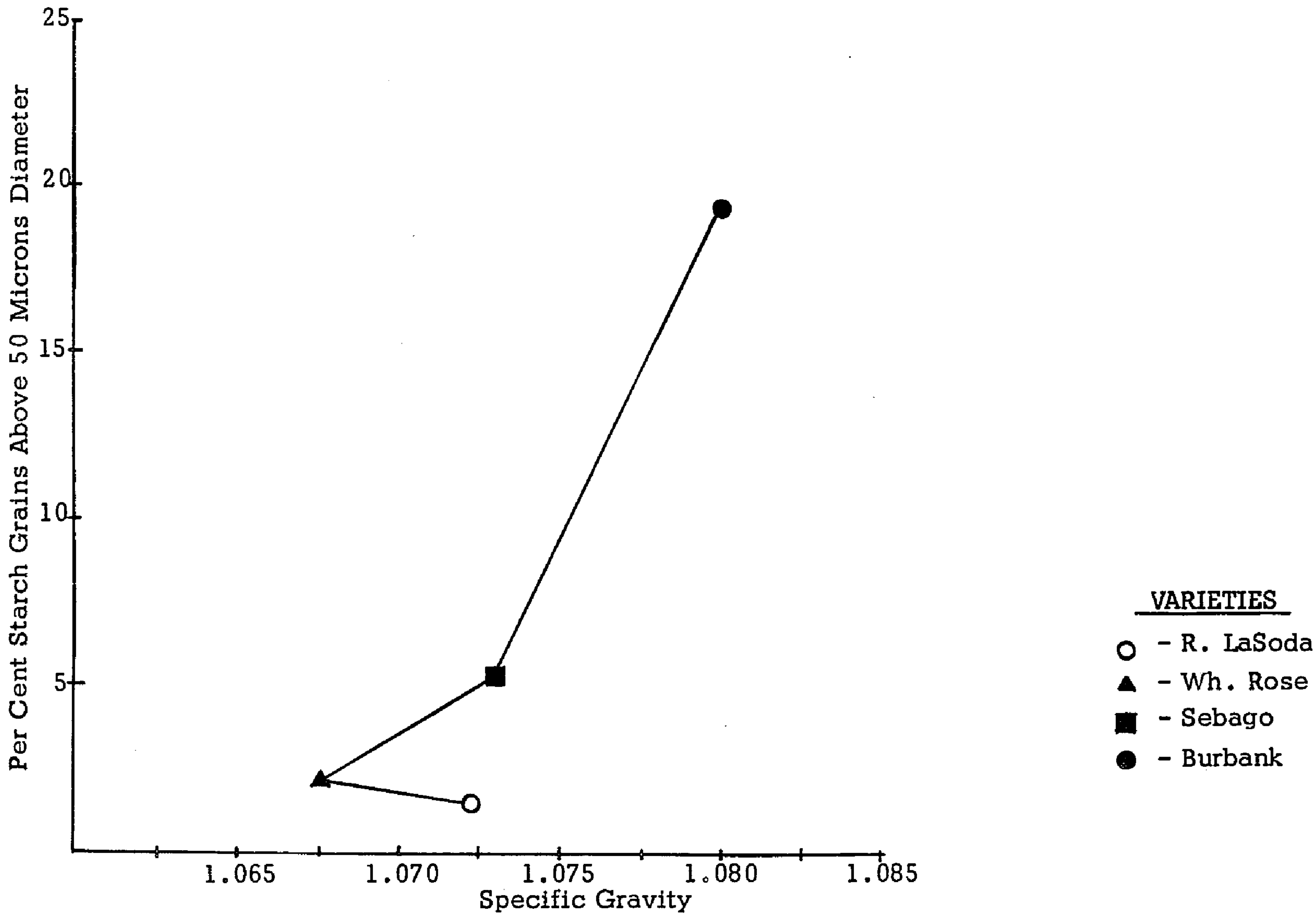

Figure 7. Relationship between specific gravity and starch grain size of northern grown tubers.

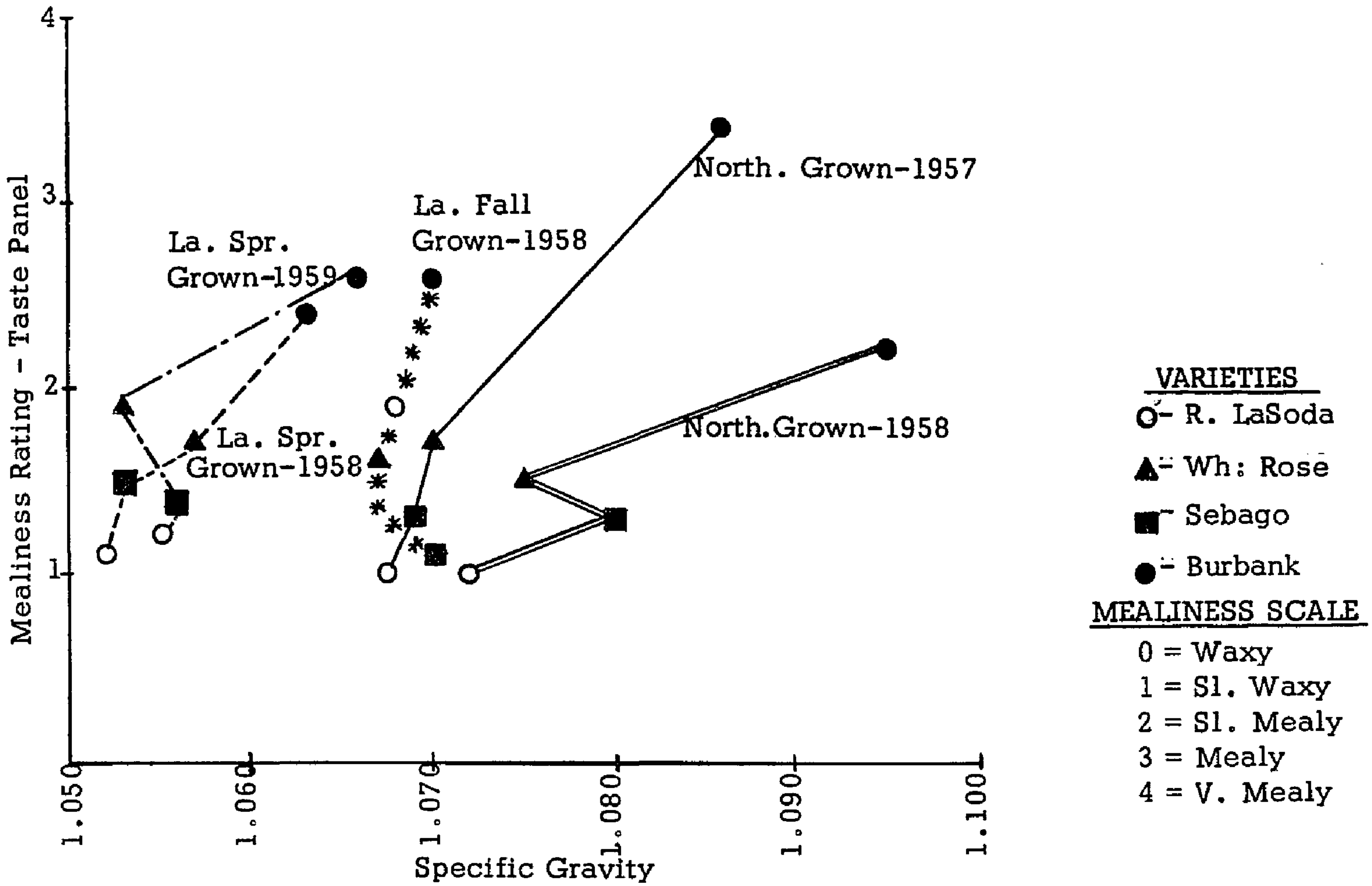

Figure 8. Effect of varieties, location, and season on the specific gravity and mealiness of potato tubers.

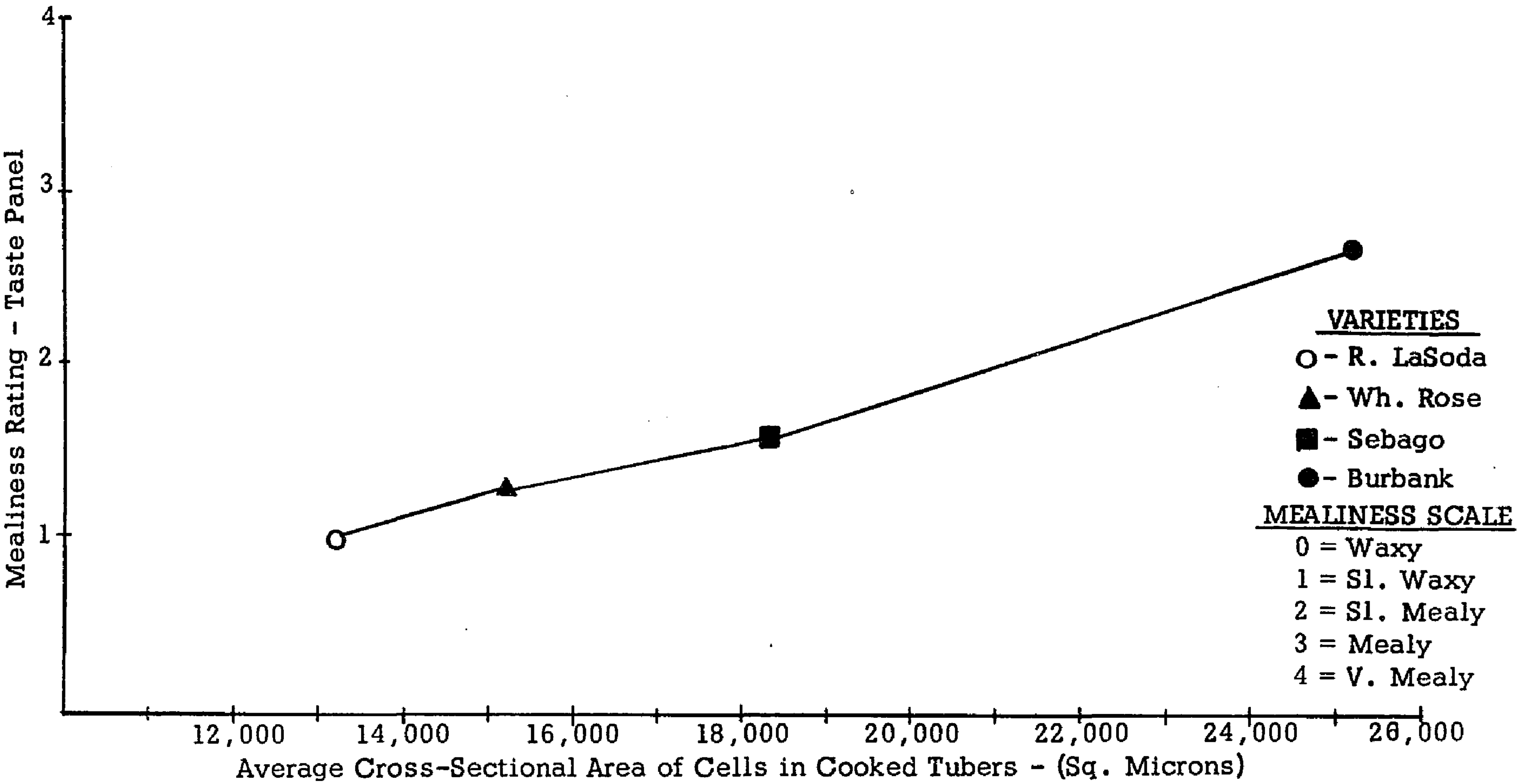

Figure 9. Relationship between cell size and mealiness of cooked northern grown tubers.

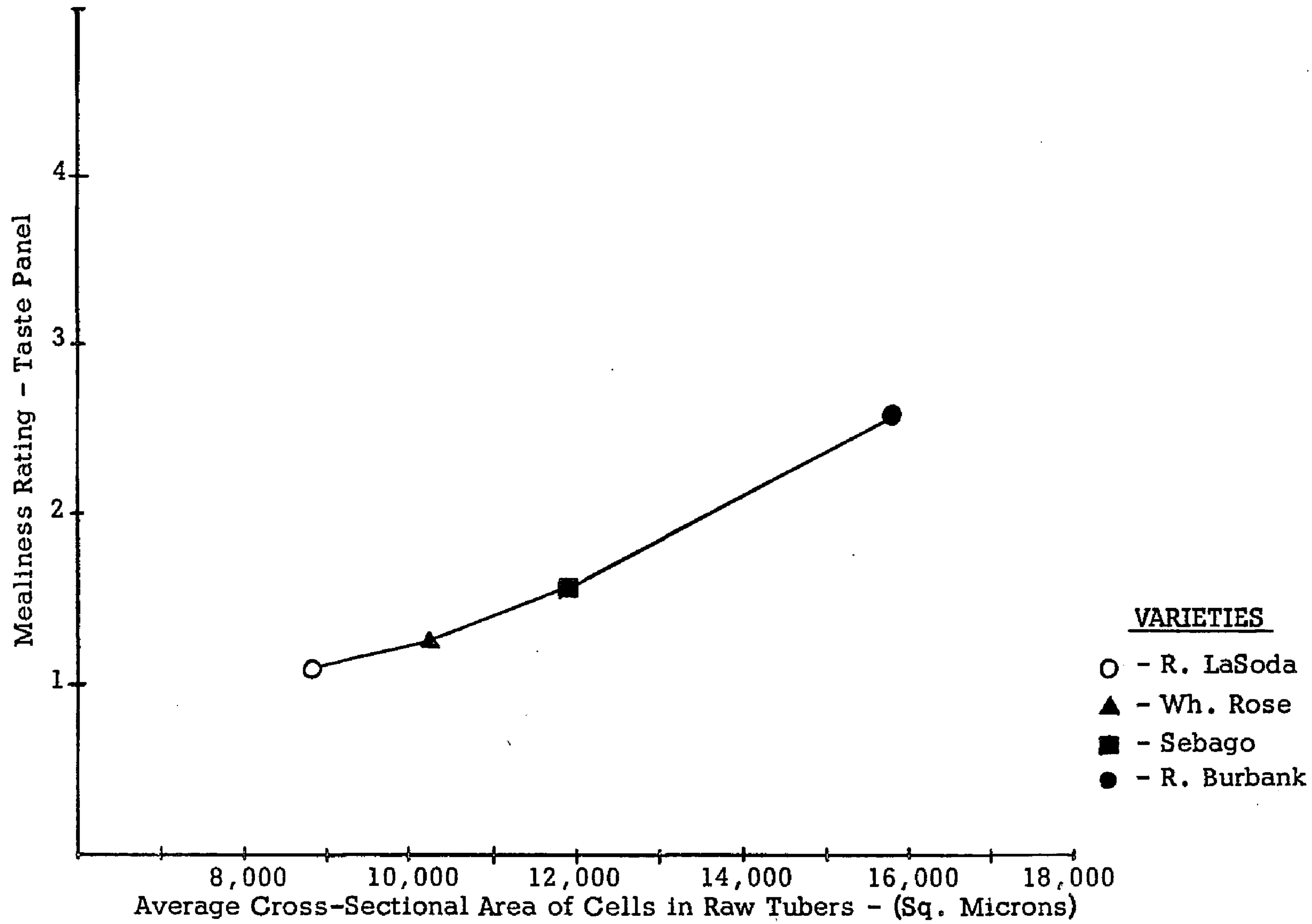

Figure 10. Relationship between cell size and mealiness of raw northern grown tubers.

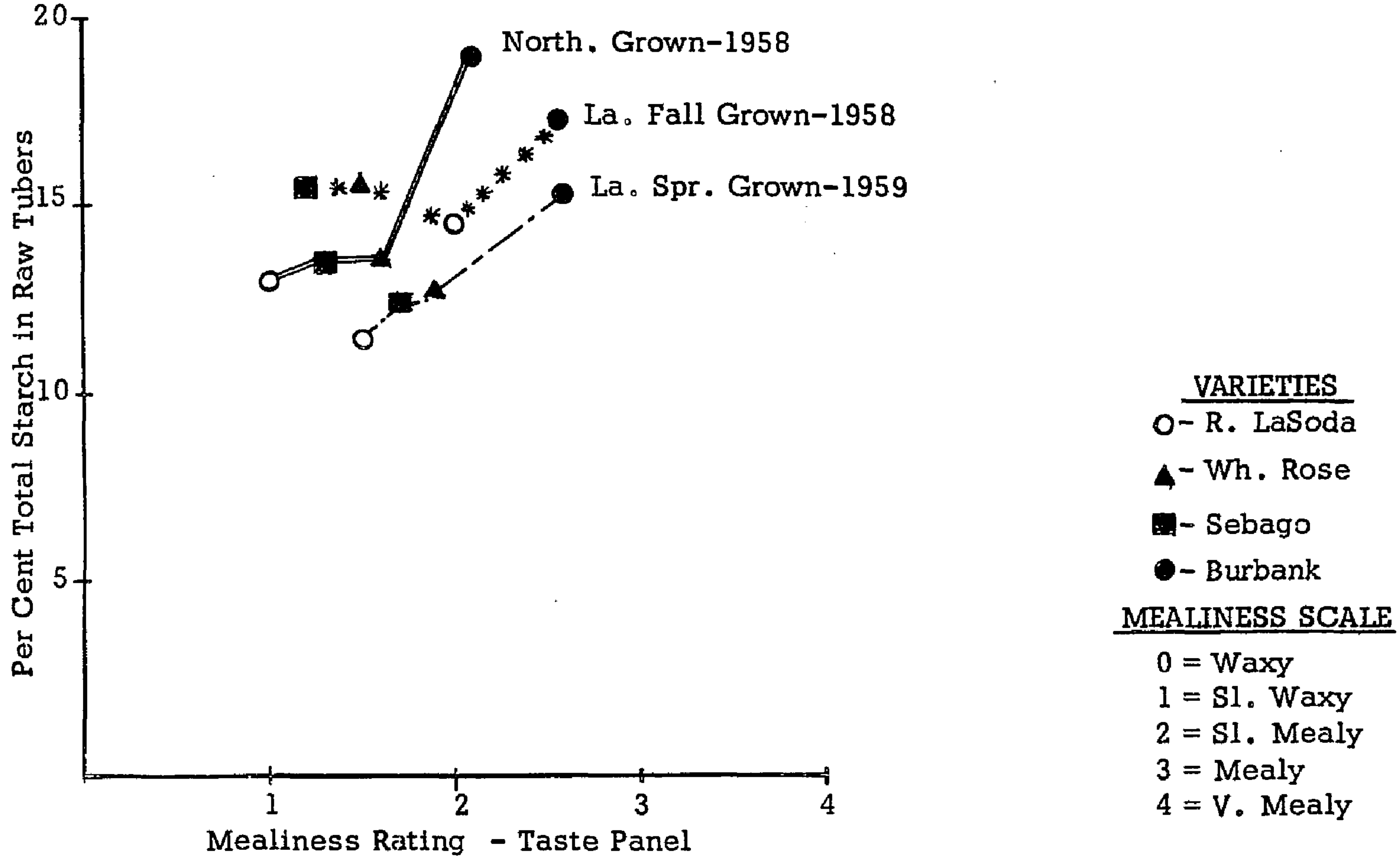

Figure 11. Effect of varieties, location, and season on the starch content and mealiness of potato tubers.

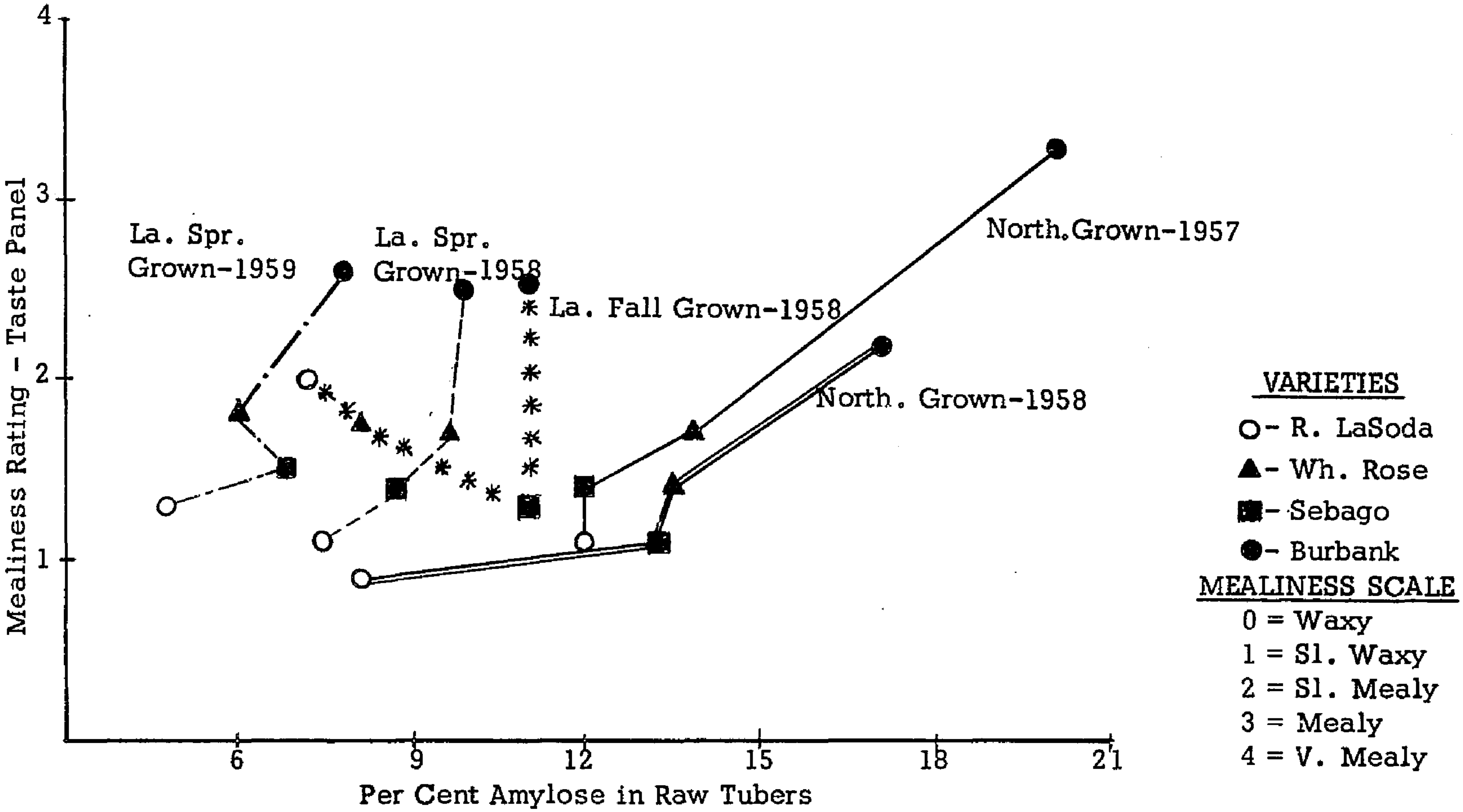

Figure 12. Effect of varieties, location, and season on the amylose content and mealiness of potato tubers.

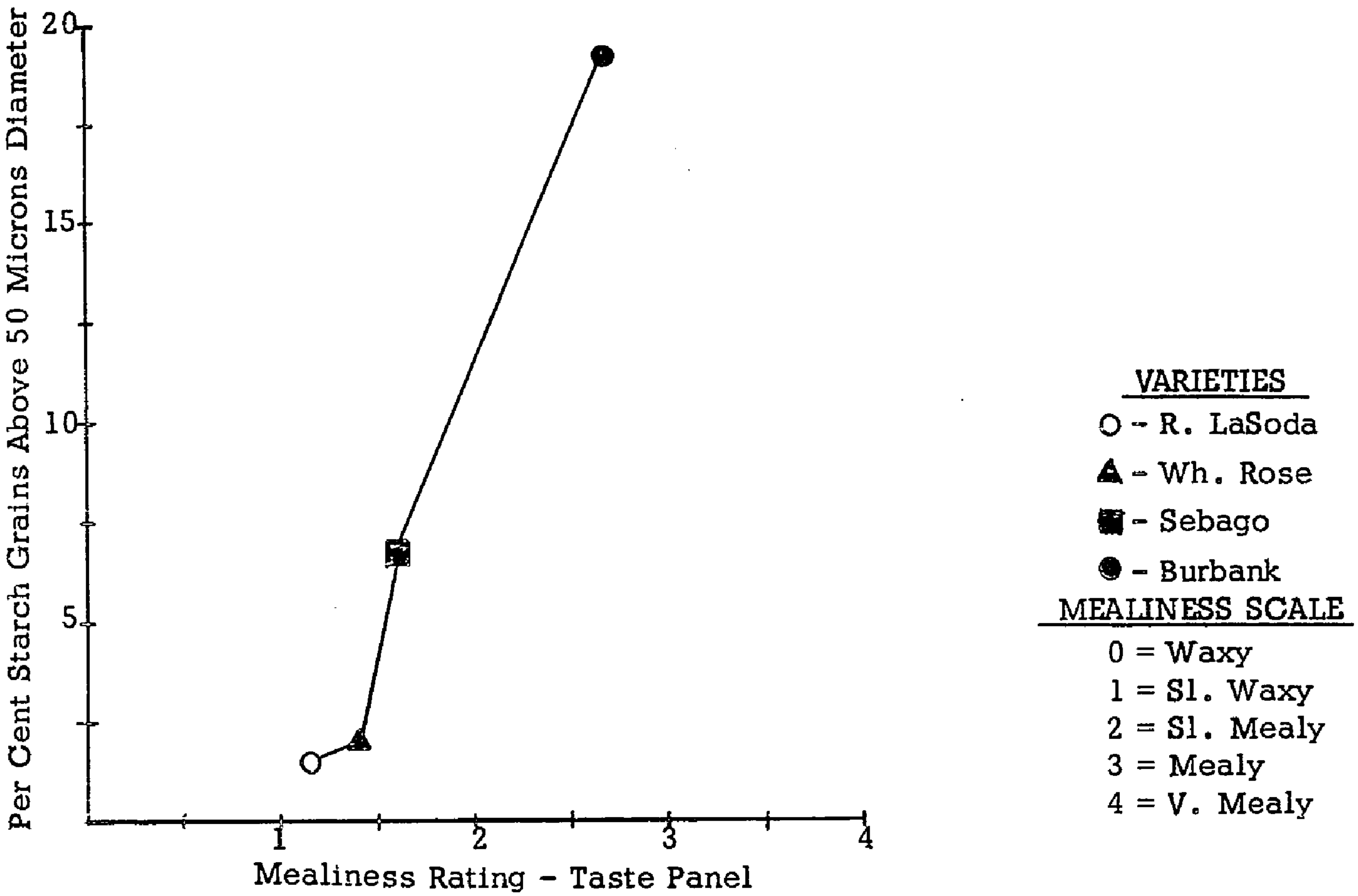

Figure 13. Relationship between starch grain size and mealiness in northern grown tubers.

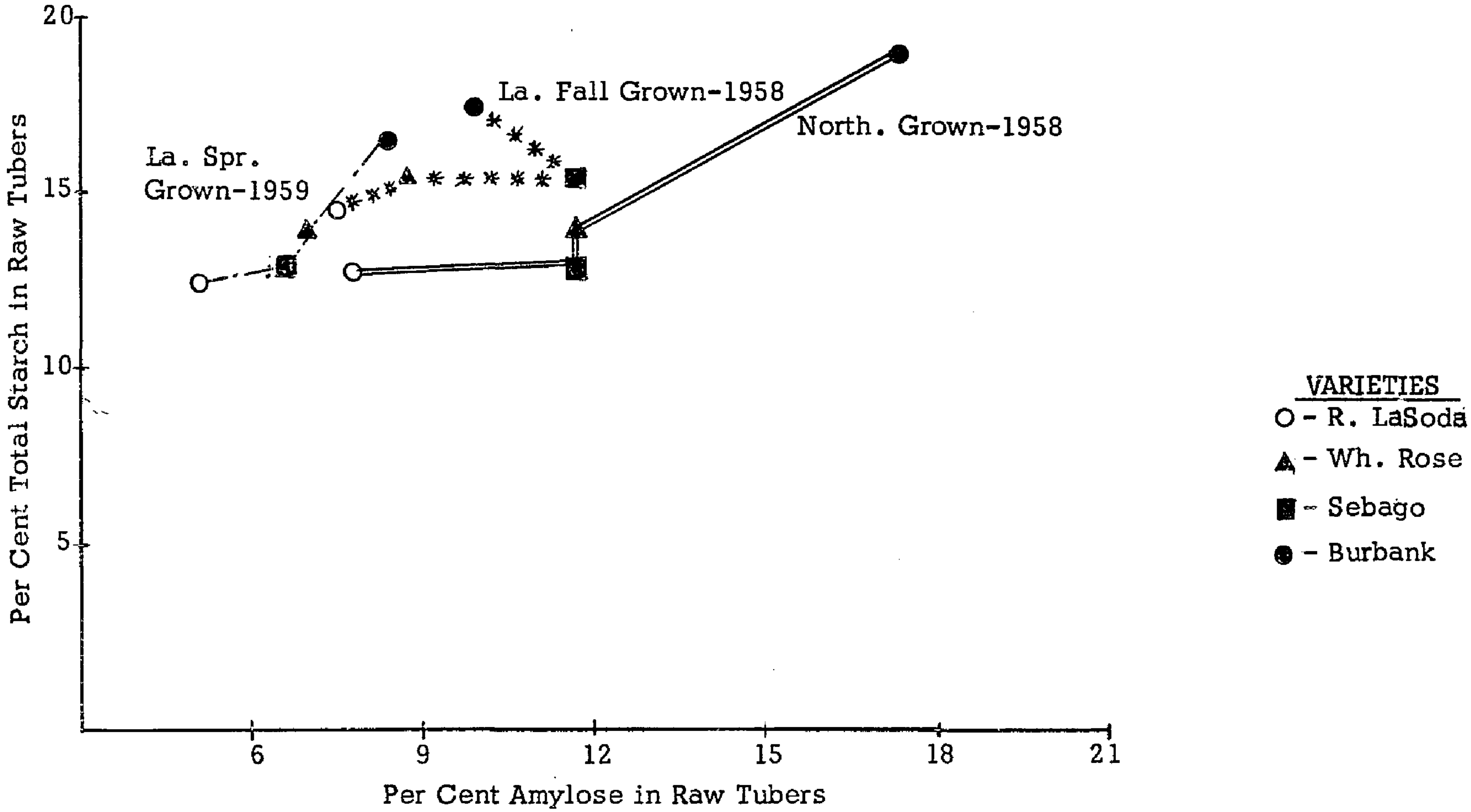

Figure 14. Effect of varieties, location, and season on the starch and amylose content of tubers.

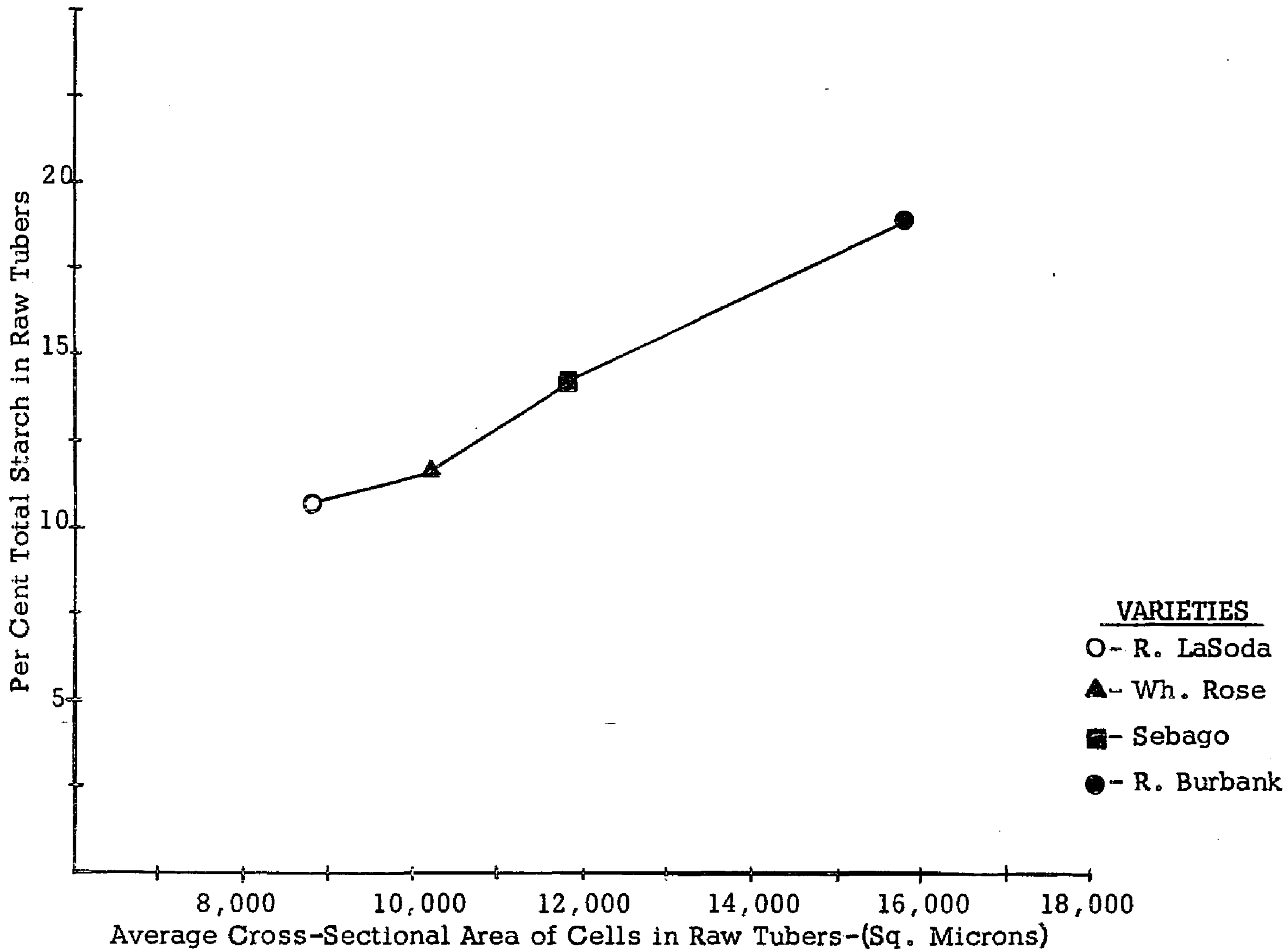

Figure 15. Relationship between cell size and total starch content of raw northern grown tubers.

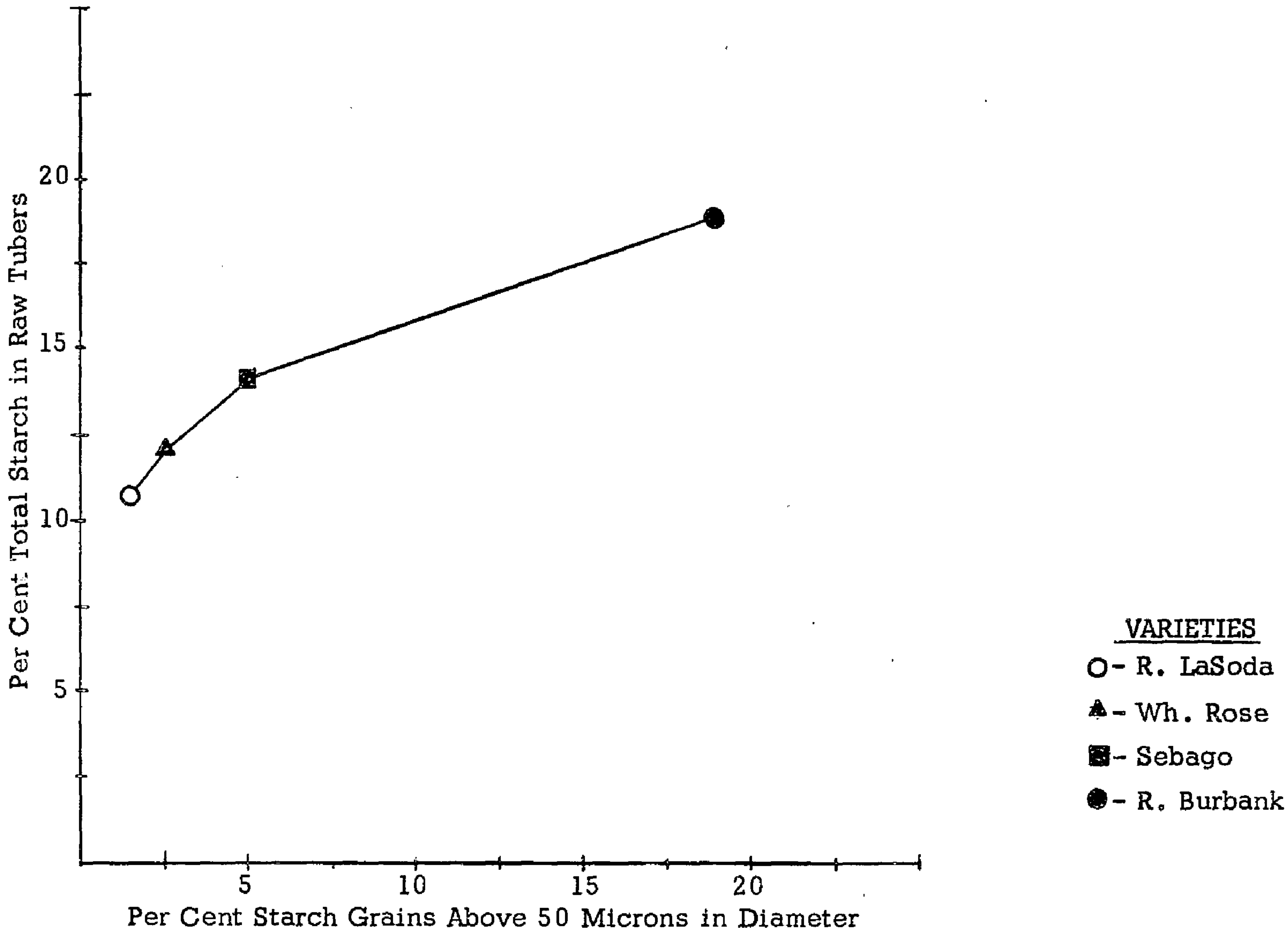

Figure 16. Relationship between starch grain size and per cent total starch in northern grown tubers.

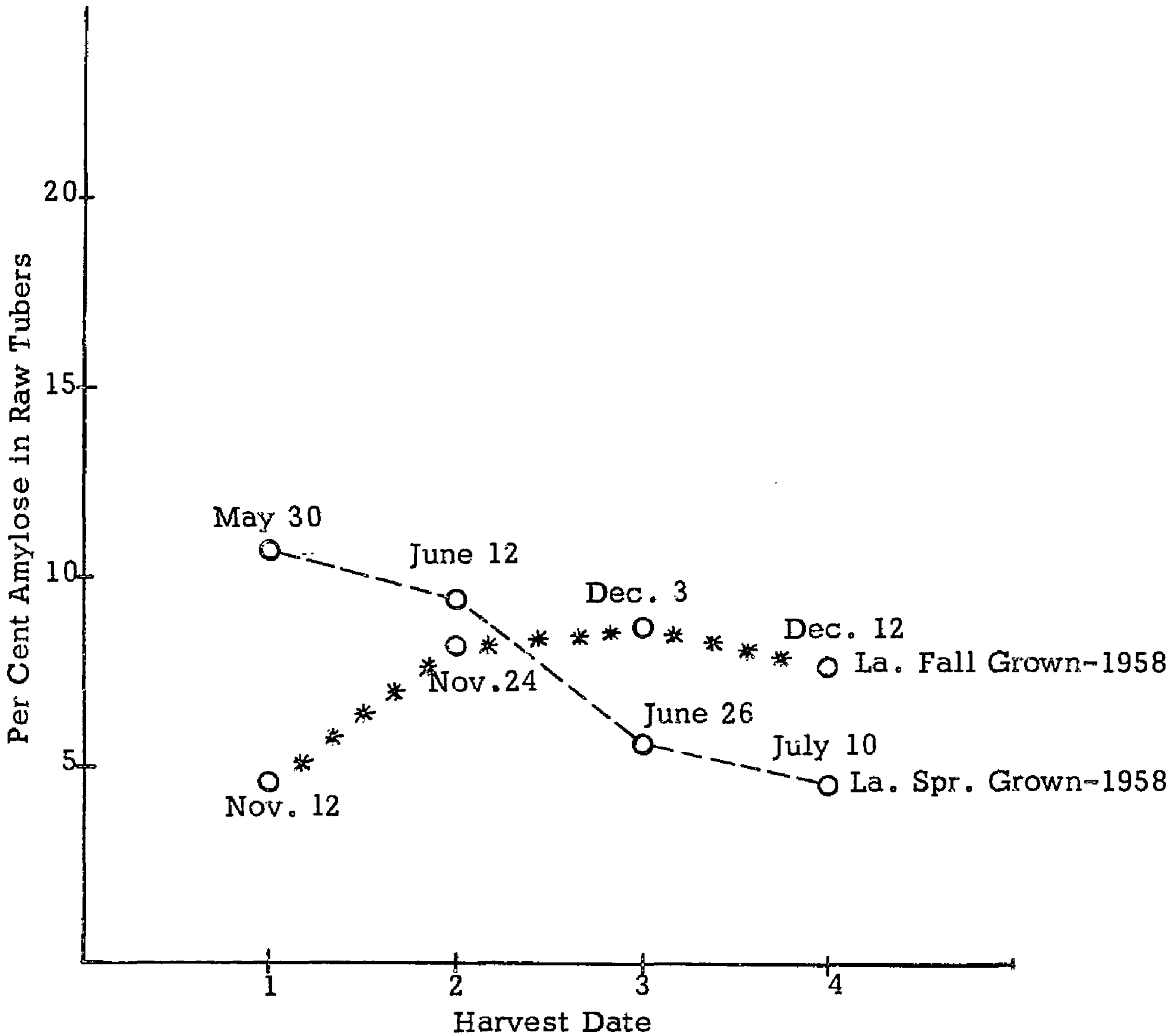

Figure 17. Effect of season and date of harvest on the amylose content of Red LaSoda potato tubers.

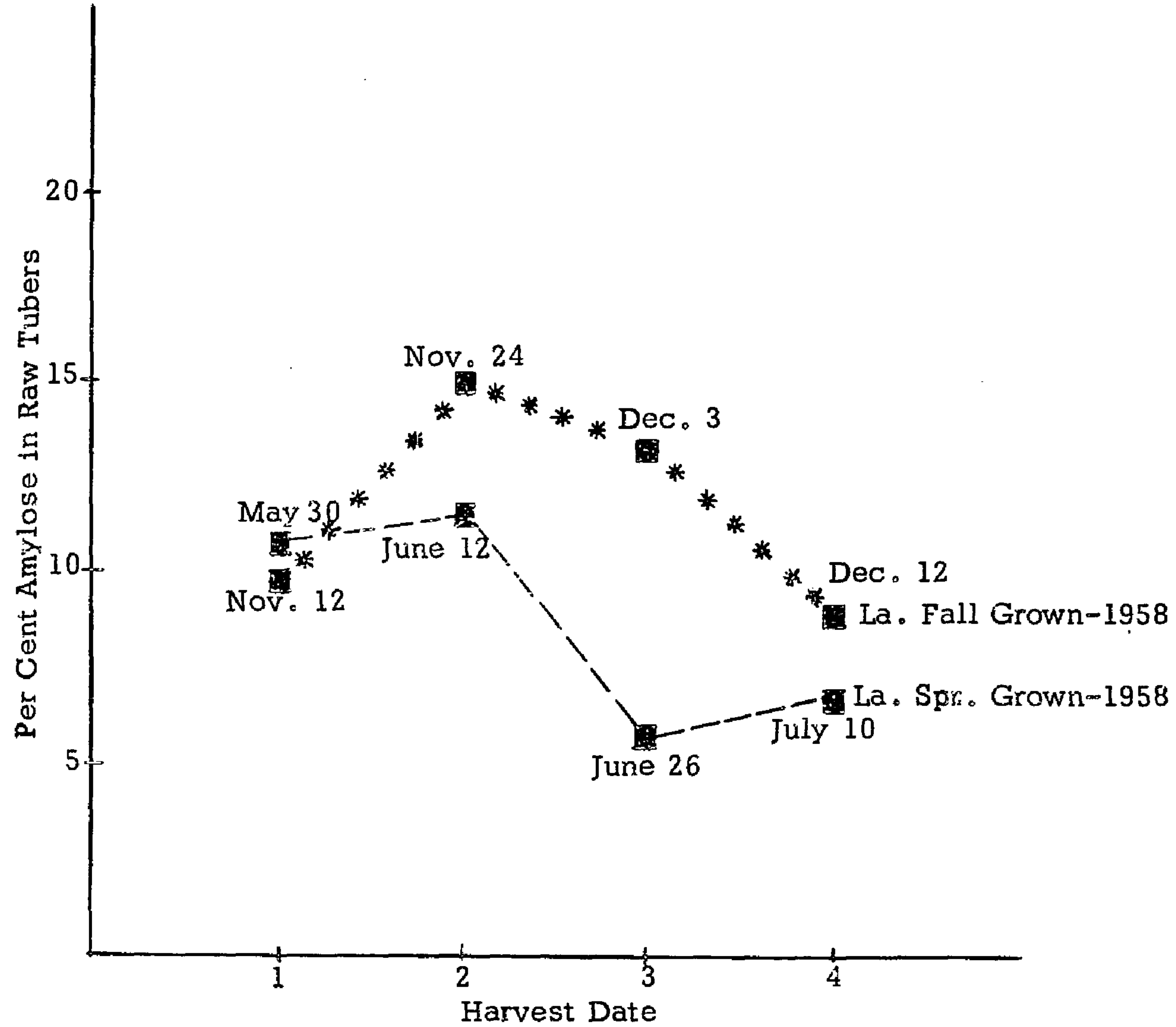

Figure 18. Effect of season and date of harvest on the amylose content of Sebago potato tubers.

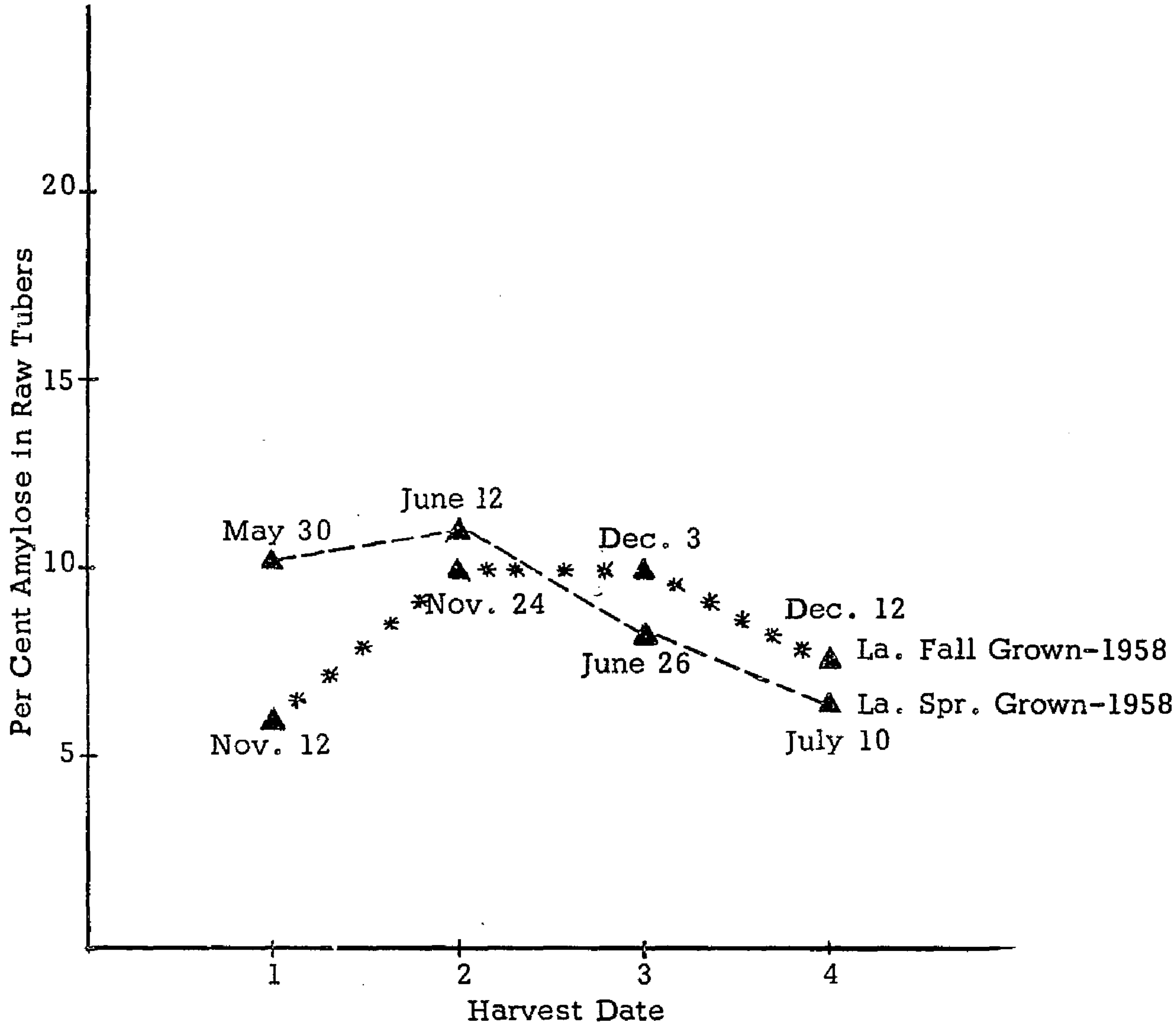

Figure 19. Effect of season and date of harvest on the amylose content of White Rose potato tubers.

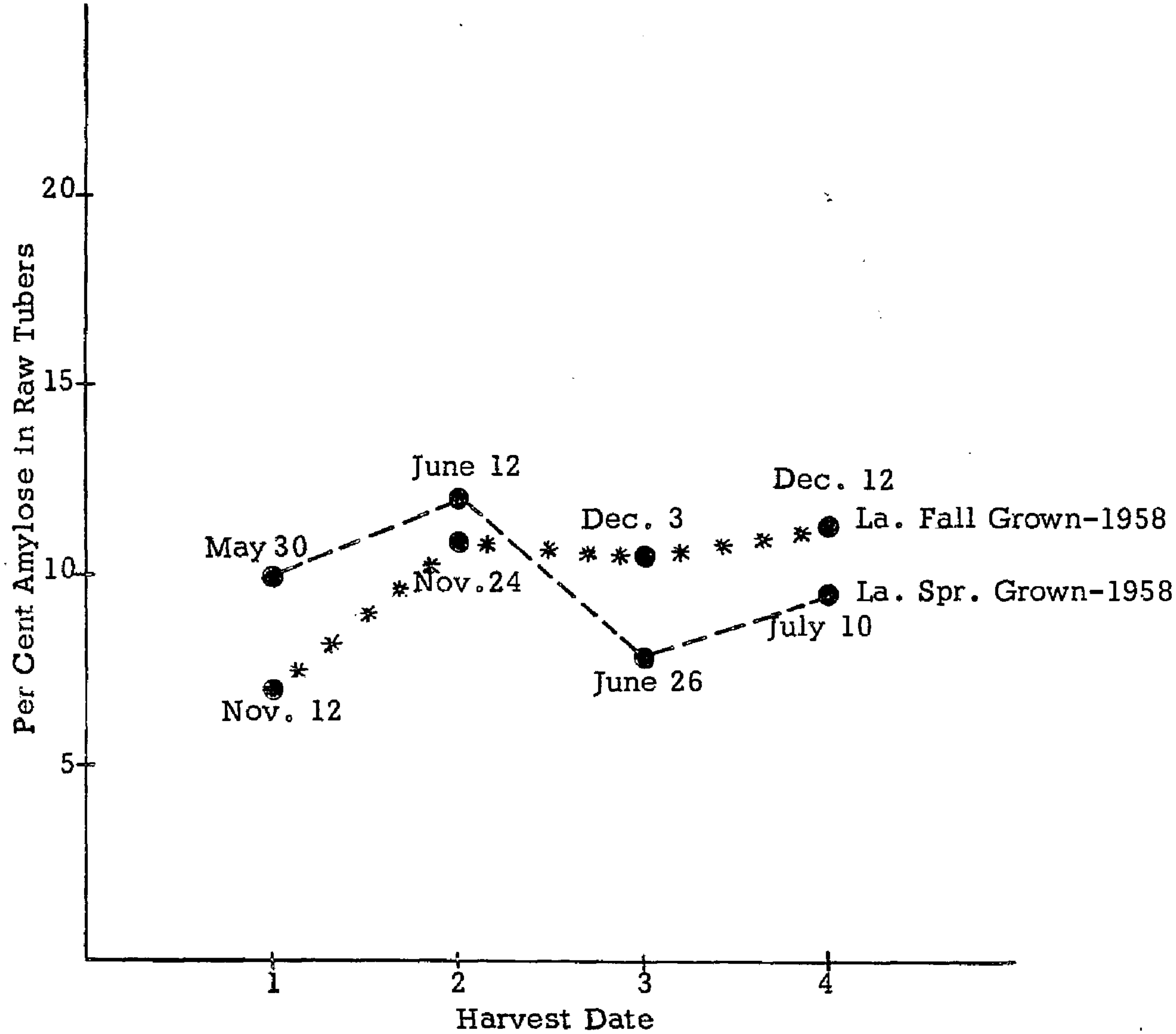

Figure 20. Effect of season and date of harvest on the amylose content of Russet Burbank potato tubers.

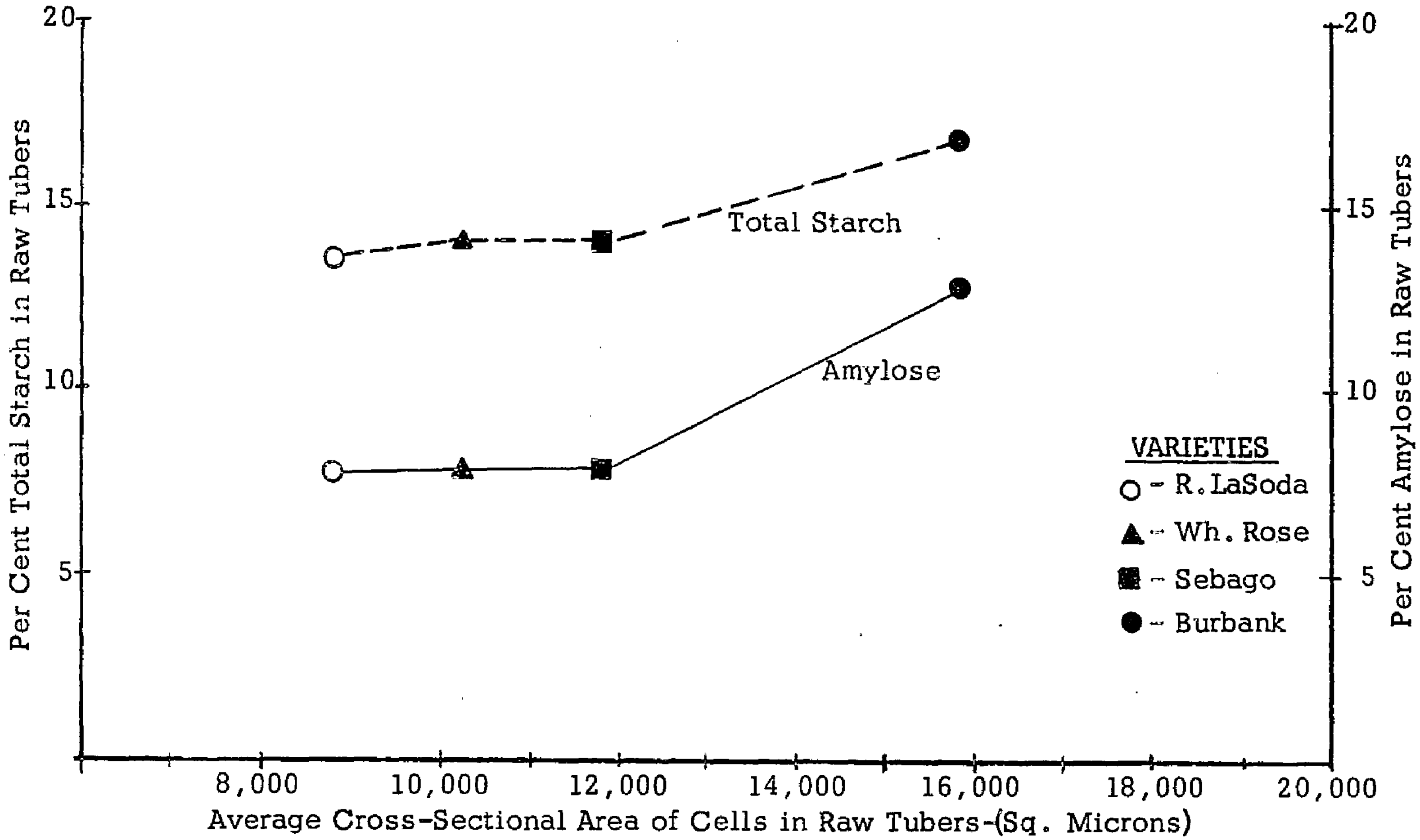

Figure 21. Relationship between the starch and amylose content and cell size of raw tubers of different varieties.

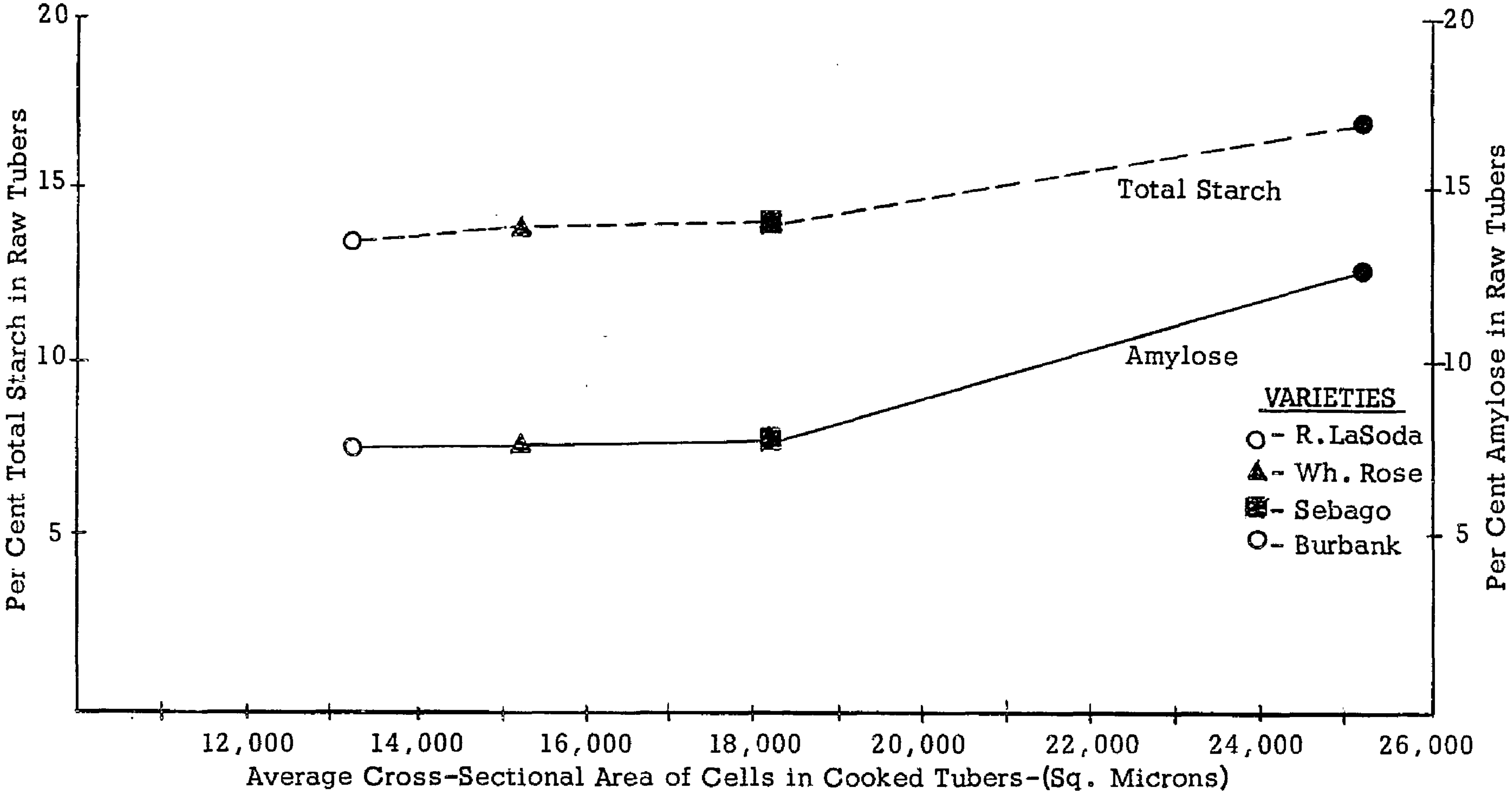

Figure 22. Relationship between the starch and amylose content of raw tubers and the cell size of cooked tubers of different varieties.

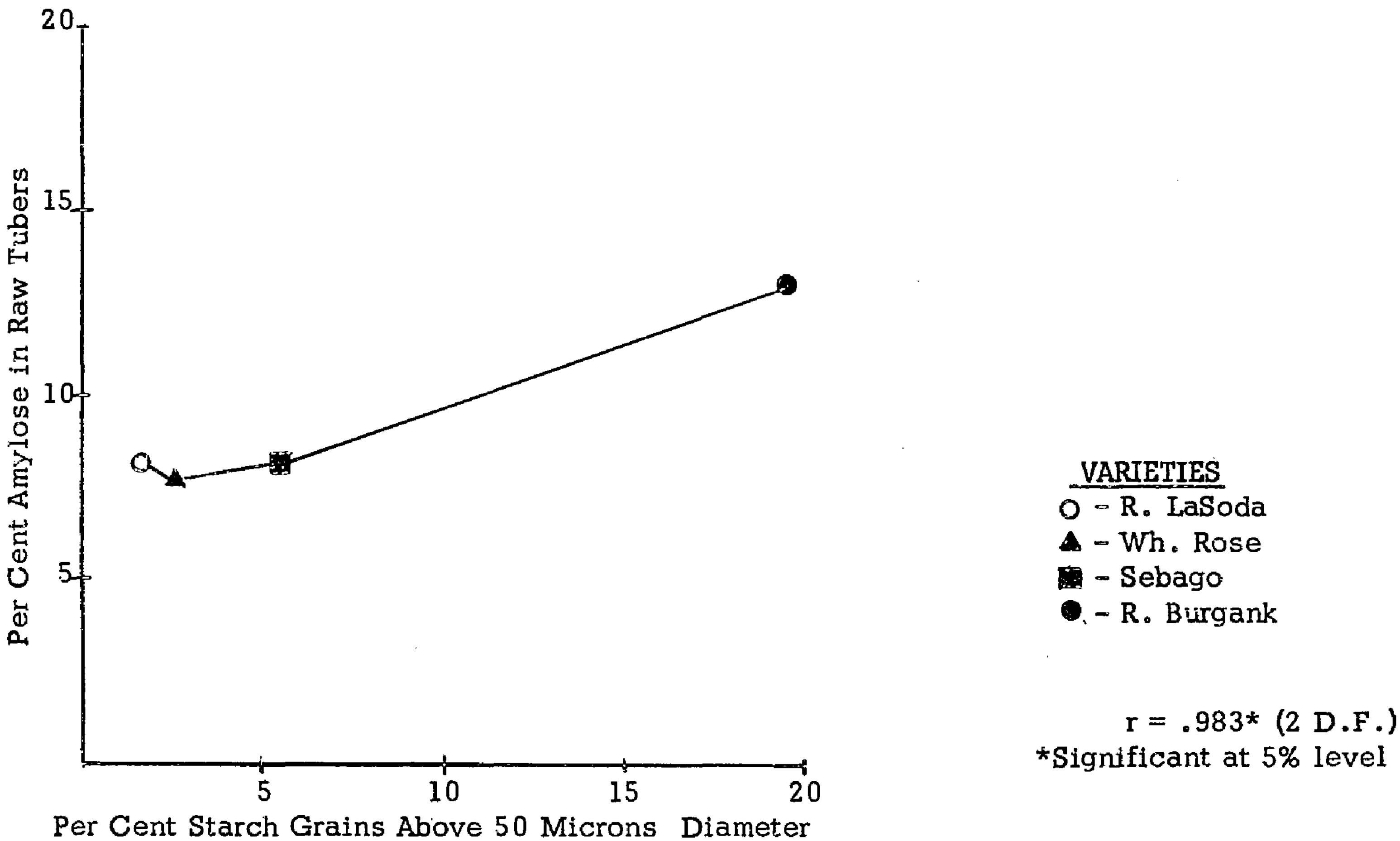

Figure 23. Relationship between starch grain size and amylose content of northern grown tubers.

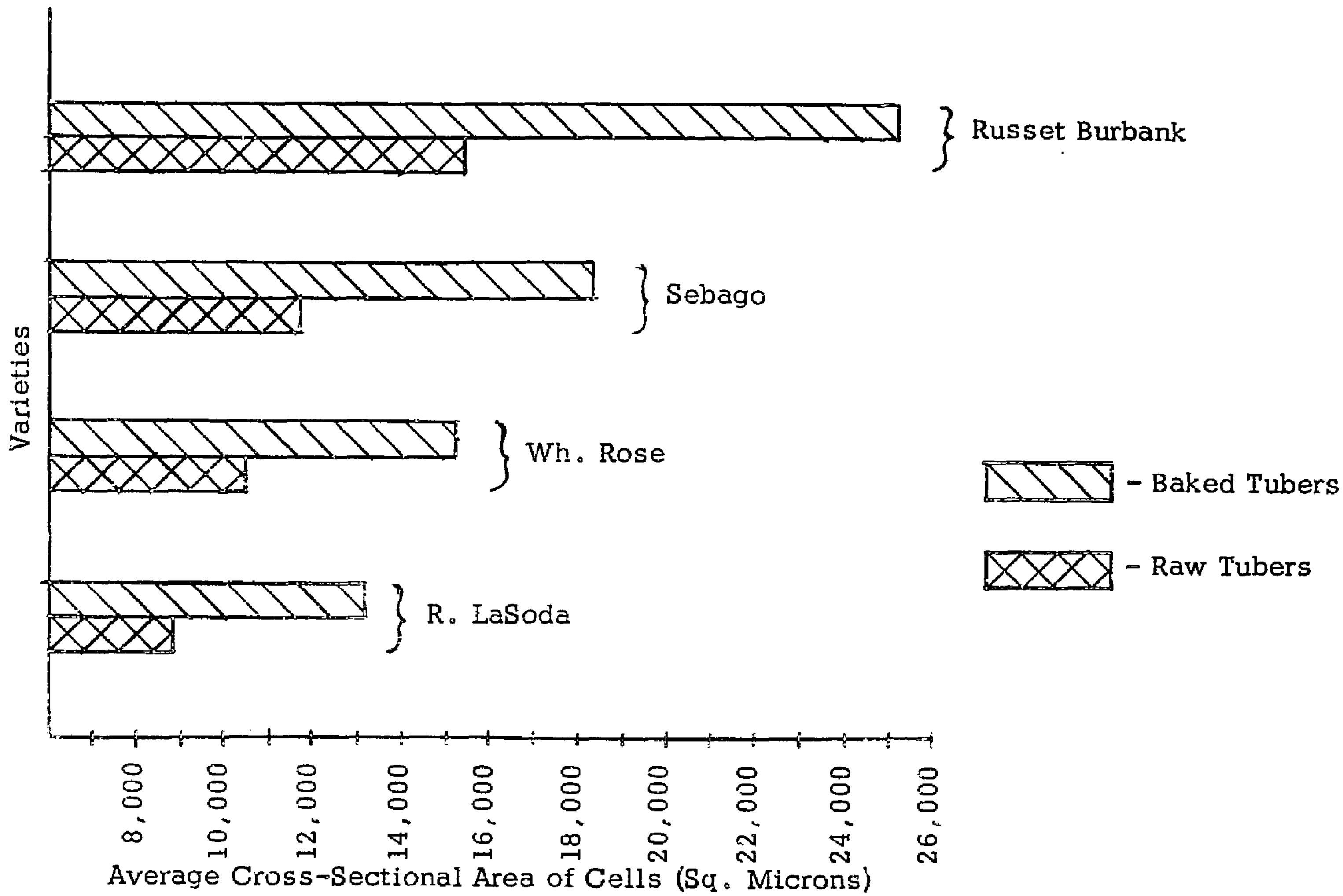

Figure 24. A comparison of cell size in tubers of different varieties and the effect of cooking on cell size.

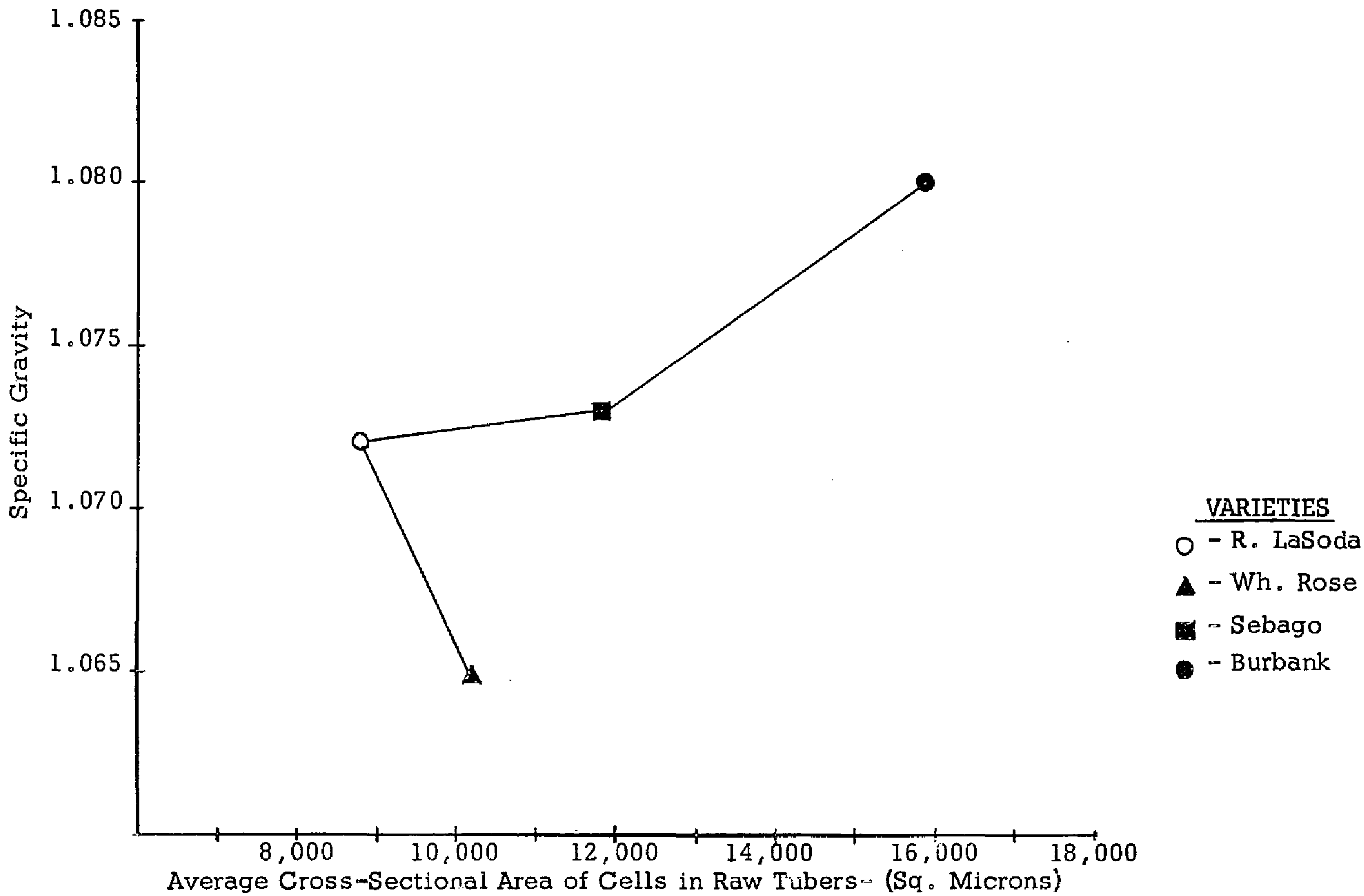

Figure 25. Relationship between cell size and specific gravity of northern grown tubers.

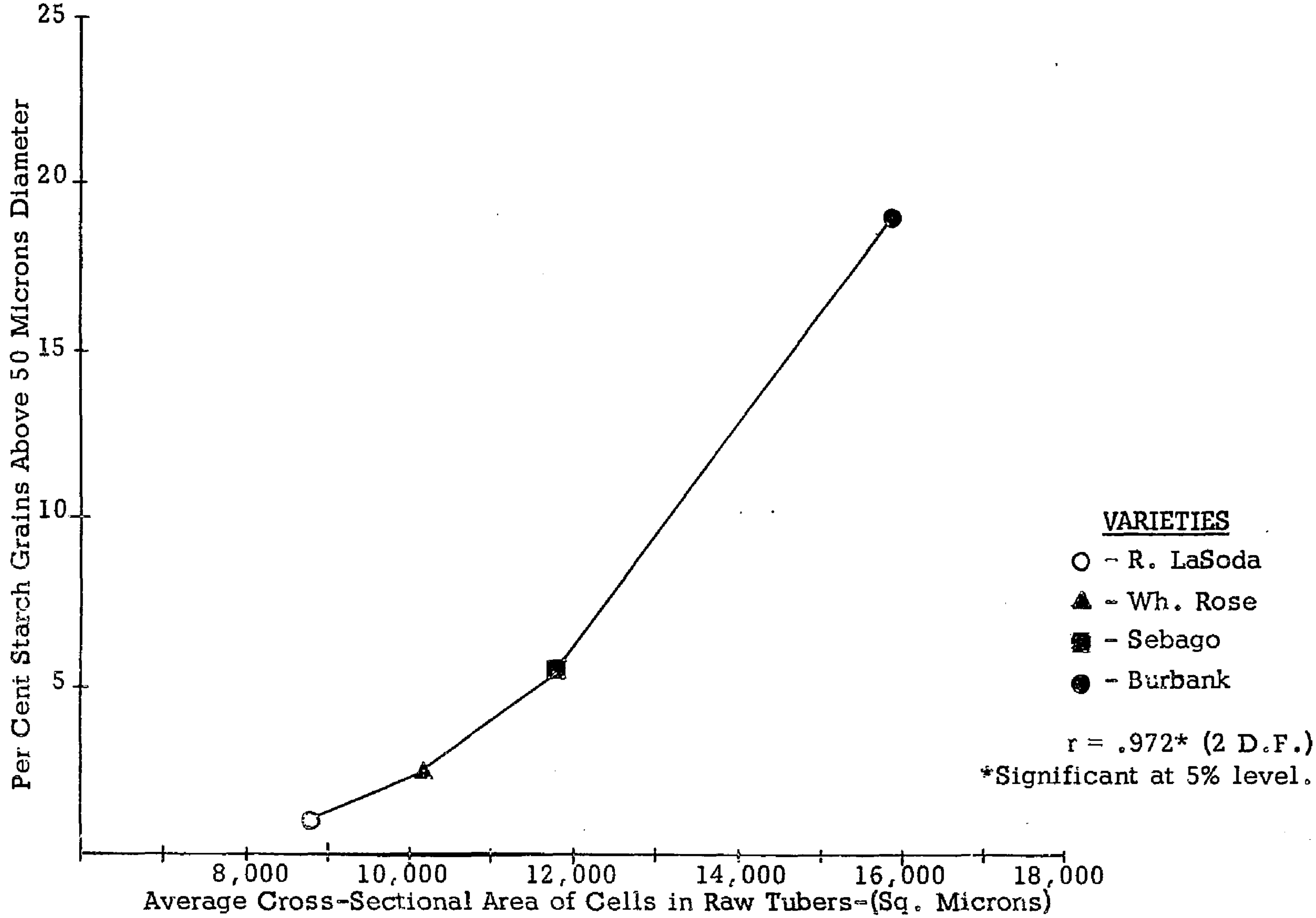

Figure 26. Relationship between cell size and starch grain size of northern grown tubers.

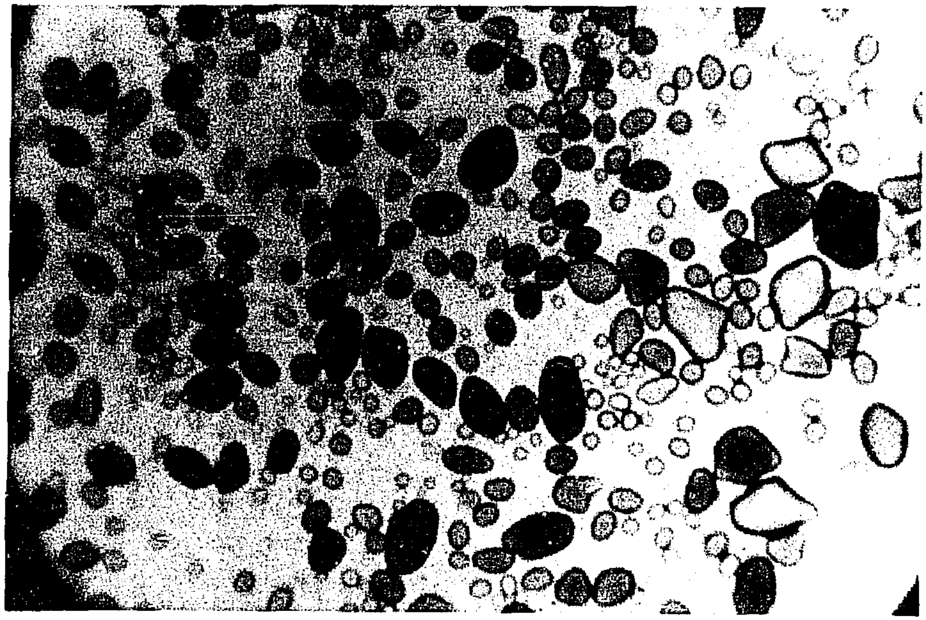

Figure 27. Photomicrograph illustrating starch grain size of raw Red LaSoda tubers (X100).

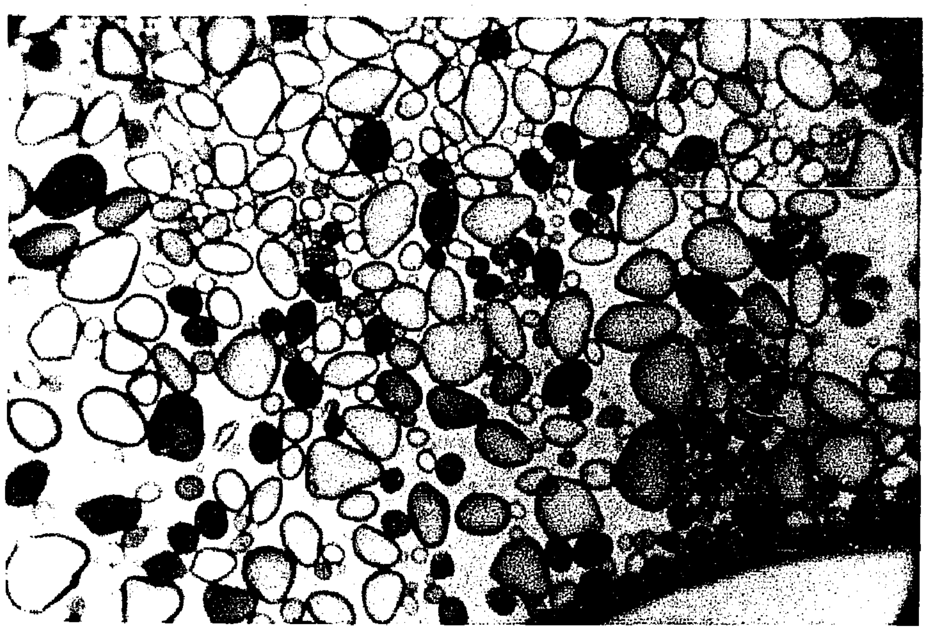

Figure 28. Photomicrograph illustrating starch grain size of raw White Rose tubers (X100).

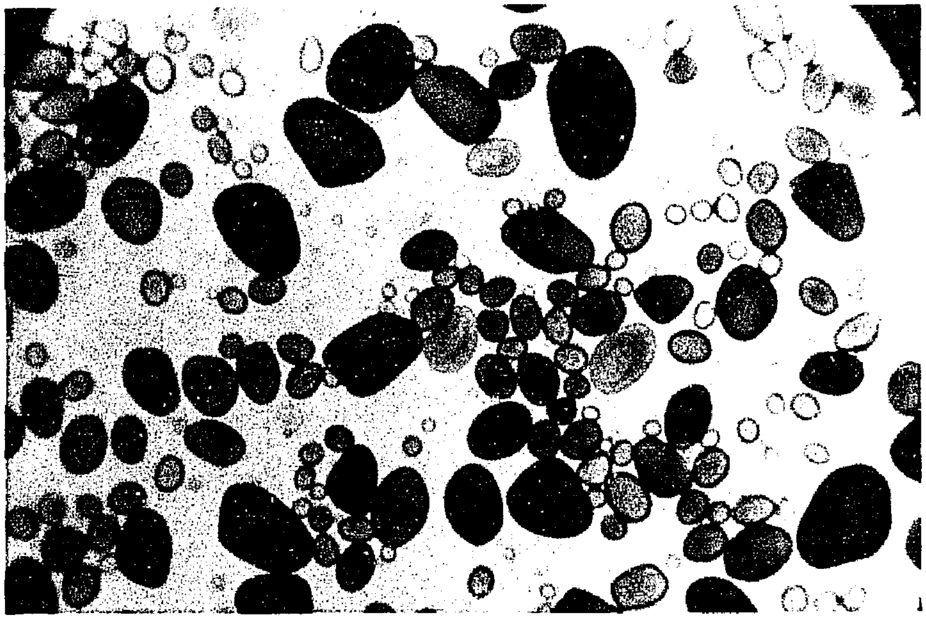

Figure 29. Photomicrograph illustrating starch grain size of raw Sebago tubers (X100).

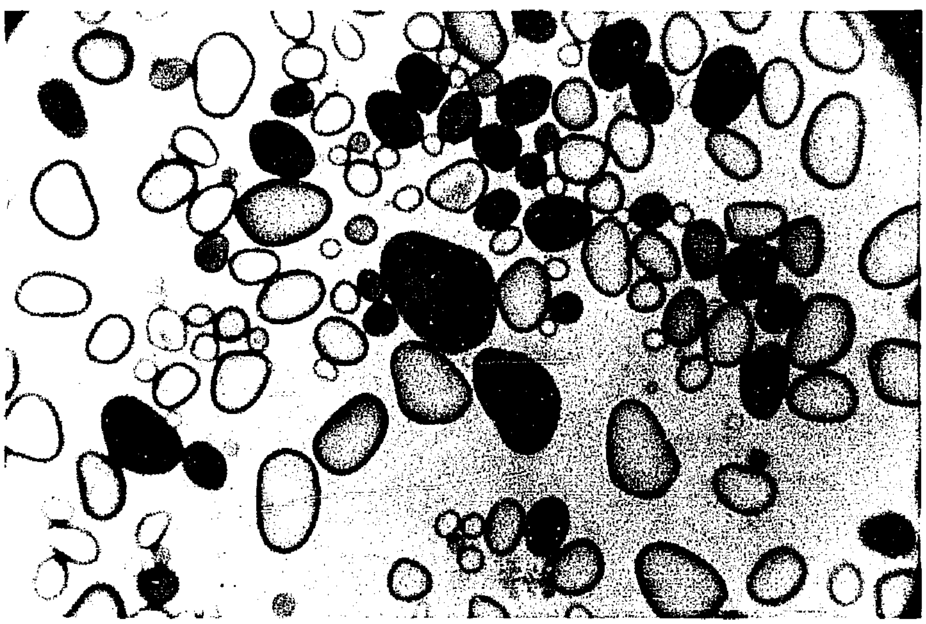

Figure 30. Photomicrograph illustrating starch grain size of raw Russet Burbank tubers (X100).

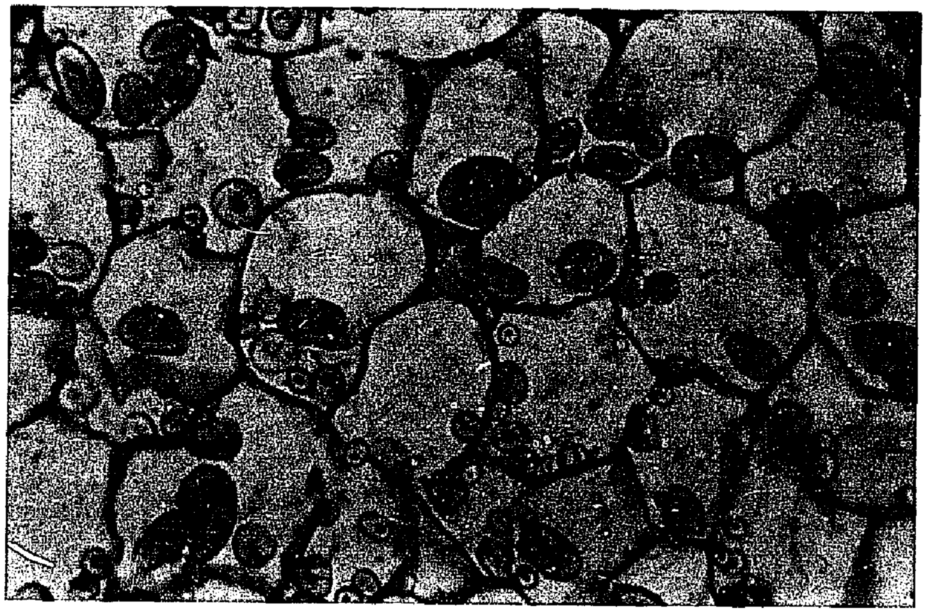

Figure 31. Photomicrograph illustrating cell size of raw Red LaSoda tubers (X100).

Figure 32. Photomicrograph illustrating cell size of raw Russet Burbank tubers (X100).

Figure 33. Photomicrograph illustrating cell size of cooked Red LaSoda tubers (X100).

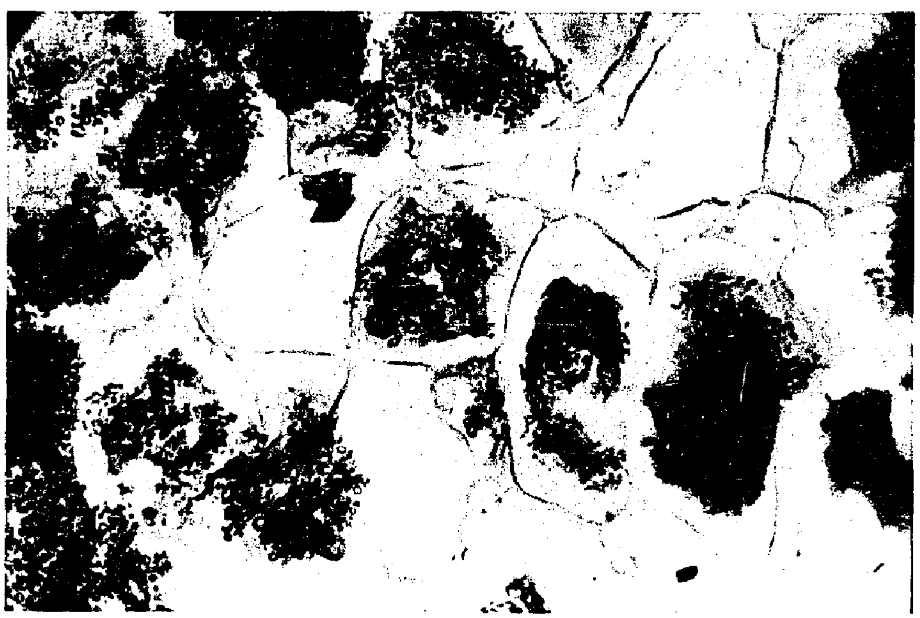

Figure 34. Photomicrograph illustrating cell size of cooked Russet Burbank tubers (X100).

AUTOBIOGRAPHY

Earl Philip Barrios, Jr. was born on December 14, 1919, in New Orleans, Louisiana. He attended elementary and high schools in Donaldsonville, Louisiana, entered Louisiana State University in 1936, receiving the Bachelor of Science degree in June, 1940, and the Master of Science degree in June, 1942. He was then employed as Potato Seed Certification manager by the State of South Dakota until 1946, then moved to Scottsbluff, Nebraska as Assistant Seed Potato Certification manager. In 1948 he was employed by the Nebraska State Department of Agriculture as Chief of the Potato Development Division, engaged in the promotion and development of Nebraska potatoes. He resigned during 1954 to work in the agricultural supply business at Nebraska. In September of 1957 he again enrolled at Louisiana State University and is now a candidate for the degree of Doctor of Philosophy in Horticulture.

EXAMINATION AND THESIS REPORT

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Major Field: Horticulture/Plant Pathology

Title of Thesis: Some Factors Influencing the Culinary Quality of Southern and Northern Grown Irish Potatoes

Approved:

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Date of Examination:

May 5, 1960